STRATHCLYDE

DISCUSSION PAPERS IN ECONOMICS

TECHNICAL APPENDIX TO: UNDERSTANDING LIQUIDITY AND CREDIT RISKS IN THE FINANCIAL CRISIS*

BY

DEBORAH GEFANG, GARY KOOP AND SIMON M. POTTER

NO. 11-15

DEPARTMENT OF ECONOMICS
UNIVERSITY OF STRATHCLYDE
GLASGOW

Technical Appendix to: Understanding Liquidity and Credit Risks in the Financial Crisis*

Deborah Gefang
Department of Economics
University of Lancaster
email: d.gefang@lancaster.ac.uk

Gary Koop
Department of Economics
University of Strathclyde
email: Gary.Koop@strath.ac.uk

Simon M. Potter
Research and Statistics Group
Federal Reserve Bank of New York
email: simon.potter@ny.frb.org

October 2010

1 The Gibbs Sampler

This section describes the detailed Gibbs sampler for Bayesian estimation. For all notation, please see the original paper.

1.1 Generating L_{kt} and C_t

To generate L_{kt} and C_t, we first transform the dynamic factor model into a state space form.

Let $S^*_{ijkt} = S_{ijkt} - \beta'_{ik} X_t$, and $D^*_{jt} = D_{jt} - \gamma' Z_t$. The measurement

*The views expressed in this paper are those of the authors and do not necessarily reflect the views of the Federal Reserve Bank of New York or the Federal Reserve System. Gary Koop is a Fellow of the Rimini Center for Economic Analysis.

equation of the model can be written as:

$$
\begin{pmatrix} D^*_{1t} \\ D^*_{2t} \\ \ldots \\ D^*_{Jt} \\ S^*_{111t} \\ S^*_{211t} \\ \ldots \\ S^*_{I11t} \\ S^*_{121t} \\ S^*_{221t} \\ \ldots \\ S^*_{I21t} \\ \ldots \\ S^*_{IJ1t} \\ S^*_{112t} \\ S^*_{212t} \\ \ldots \\ S^*_{IJ2t} \\ \ldots \\ S^*_{11Kt} \\ S^*_{21Kt} \\ \ldots \\ S^*_{IJKt} \end{pmatrix} = \begin{pmatrix} \psi^C_1 & 0 & 0 & \ldots & 0 \\ \psi^C_2 & 0 & 0 & \ldots & 0 \\ \ldots & \ldots & \ldots. & & \\ \psi^C_J & 0 & 0 & \ldots & 0 \\ \psi^S_{11} & \lambda^S_{111} & 0 & \ldots & 0 \\ \psi^S_{21} & \lambda^S_{111} & 0 & \ldots & 0 \\ \ldots & \ldots & \ldots. & & \\ \psi^S_{I1} & \lambda^S_{I11} & 0 & \ldots & 0 \\ \psi^S_{12} & \lambda^S_{121} & 0 & \ldots & 0 \\ \psi^S_{22} & \lambda^S_{221} & 0 & \ldots & 0 \\ \ldots & \ldots & \ldots. & & \\ \psi^S_{I2} & \lambda^S_{I21} & 0 & \ldots & 0 \\ \ldots & \ldots & \ldots. & & \\ \psi^S_{IJ} & \lambda^S_{IJ1} & 0 & \ldots & 0 \\ \psi^S_{11} & 0 & \lambda^S_{112} & \ldots & 0 \\ \psi^S_{21} & 0 & \lambda^S_{212} & \ldots & 0 \\ \ldots & \ldots & \ldots. & & \\ \psi^S_{IJ} & 0 & \lambda^S_{IJ2} & \ldots & 0 \\ \ldots & \ldots & \ldots. & & \\ \psi^S_{11} & 0 & 0 & \ldots & \lambda^S_{11K} \\ \psi^S_{21} & 0 & 0 & \ldots & \lambda^S_{21K} \\ \ldots & \ldots & \ldots. & & \\ \psi^S_{IJ} & 0 & 0 & \ldots & \lambda^S_{IJK} \end{pmatrix} \begin{pmatrix} C_t \\ L_{1t} \\ .. \\ L_{Kt} \end{pmatrix} + \begin{pmatrix} \varepsilon^D_{1t} \\ \varepsilon^D_{2t} \\ \ldots \\ \varepsilon^D_{Jt} \\ \varepsilon^S_{111t} \\ \varepsilon^S_{211t} \\ \ldots \\ \varepsilon^S_{I11t} \\ \varepsilon^S_{121t} \\ \varepsilon^S_{221t} \\ \ldots \\ \varepsilon^S_{I21t} \\ \ldots \\ \varepsilon^S_{IJ1t} \\ \varepsilon^S_{112t} \\ \varepsilon^S_{212t} \\ \ldots \\ \varepsilon^S_{IJ2t} \\ \ldots \\ \varepsilon^S_{11Kt} \\ \varepsilon^S_{21Kt} \\ \ldots \\ \varepsilon^S_{IJKt} \end{pmatrix} \tag{1}
$$

$$(y_t = H\xi_t + e_t) \tag{2}$$

where $e_t \sim i.i.d.N(0, R)$, the size of y_t is $J + IJK$ by 1, the size of H is $J + IJK$ by $1 + K$, and the size of ξ_t is $1 + K$ by 1.

The transition equation can be written as

$$
\begin{pmatrix} C_t \\ L_{1t} \\ \ldots \\ L_{Kt} \end{pmatrix} = \begin{pmatrix} \phi^C_0(s^C_t) \\ \phi^L_{10}(s^L_t) \\ \ldots \\ \phi^L_{K0}(s^L_t) \end{pmatrix} + \begin{pmatrix} \phi^C_1(s^C_t) & 0 & \ldots & 0 \\ 0 & \phi^L_{11}(s^L_t) & \ldots & 0 \\ \ldots & & & \\ 0 & 0 & \ldots & \phi^L_{K1}(s^L_t) \end{pmatrix} \begin{pmatrix} C_{t-1} \\ L_{1,t-1} \\ \ldots \\ L_{K,t-1} \end{pmatrix} + \begin{pmatrix} \sigma_C(s^C_t)\nu^C_t \\ \sigma_{1L}(s^L_t)\nu^L_{1t} \\ \ldots \\ \sigma_{KL}(s^L_t)\nu^L_{Kt} \end{pmatrix} \tag{3}
$$

$$(\xi_t = \mu_t + F_t\xi_{t-1} + \epsilon_t) \tag{4}$$

where $\epsilon_t \sim i.i.d.N(0, Q_t)$, the size of ξ_t is $1 + K$ by 1, the size of μ_t is $1 + K$ by 1, and the size of F_t is $1 + K$ by $1 + K$.

Let $\widetilde{y}_t = (y_1, y_2, ..., y_t)^{'}$. Following Kim and Nelson (1999, Ch. 8), we can draw the latent risk factors in the following two steps.

First run Kalman filter to calculate $\xi_{t|t} = E(\xi_t|\widetilde{y}_t)$ and $P_{t|t} = Cov(\xi_t|\widetilde{y}_t)$ for $t = 1, 2, ..., T$:

$$\xi_{t|t-1} = \mu_t + F_t\xi_{t-1}$$

$$P_{t|t-1} = F_t P_{t|t-1} F_t^{'} + Q_t$$

$$\xi_{t|t} = \xi_{t|t-1} + P_{t|t-1}H^{'}(HP_{t|t-1}H^{'} + R)^{-1}(y_t - H\xi_{t|t-1})$$

$$P_{t|t} = P_{t|t-1} - P_{t|t-1}H^{'}(HP_{t|t-1}H^{'} + R)^{-1}HP_{t|t-1}$$

Next, we draw ξ_T based on the last iteration of the Kalman filter:

$$\xi_T|\widetilde{y}_T \sim N(\xi_{T|T}, P_{T|T})$$

Let $\xi_{t+1} = (C_{t+1}, L_{1,t+1}, ..., L_{K,t+1})'$. We have

$$\xi_{t+1} = \mu_{t+1} + F_{t+1}\xi_t + \epsilon_{t+1}$$

Defining Q_{t+1} the variance of ϵ_{t+1}, for $t = T-1, T-2, ..., 1$, we can derive $\xi_{t|\widetilde{y}_T}$ backward from

$$\xi_t|\widetilde{y}_t, \xi_{t+1} \sim N(\xi_{t|t,\xi_{t+1}}, P_{t|t,\xi_{t+1}})$$

where

$$\xi_{t|t,\xi_{t+1}} = \xi_{t|t} + P_{t|t}F_{t+1}^{'}\{F_{t+1}P_{t|t}F_{t+1}^{'} + Q_{t+1}\}^{-1}(\xi_{t+1} - \mu_{t+1} - F_{t+1}\xi_{t|t})$$

$$P_{t|t,\xi_{t+1}} = P_{t|t} - P_{t|t}F_{t+1}^{'}\{F_{t+1}P_{t|t}F_{t+1}^{'} + Q_{t+1}\}^{-1}F_{t+1}P_{t|t}$$

There are many observations missing, especially in the CDS data. To treat the missing elements in y_t, following Durbin and Koopman (2008, Ch. 4), we replace y_t, H and R by y_t^*, H_t^* and R_t^*, where $y_t^* = W_t y_t$, $H_t^* = W_t H$ and $R_t^* = W_t R W_t^{'}$, with W_t being the known matrix whose rows are a subset of rows of the identity matrix I_{J+IJK} that correspond to the observed values in y_t. Thus, we adjust the dimensions of H and R to account for the fact that there is no new information added to the Kalman filter when data are missing.[1]

1.2 Draw Parameters for the Measurement Equations

- **Generating σ^2_{ijkS}, Conditional on S_{ijkt}, λ^S_{ijk}, ψ^S_{ij}, β_{ik}, L_{kt} and C_t.**

Prior
$h_{ijkS} \sim G(\underline{s}^{-2}_{ijkS}, \underline{\nu}_{ijkS})$

where $h_{ijkS} = \sigma^{-2}_{ijkS}$. G denotes a Gamma distribution. Details of the distribution can be found in Koop (2003, p.326).

[1] Since generated missing observations contain no new data information aside from the parameters, we don't take them as observed in the Kalman filter. In practice, we find that otherwise the Gibbs sampler hardly converges. Using balanced panel data where rows with missing observations simply deleted, we find very similar results for latent risk factors.

Posterior
$h_{ijkS}|S_{ijkt}, \lambda^S_{ijk}, \psi^S_{ij}, \beta_{ik}, L_{kt}, C_t \sim G(\overline{s}^{-2}_{ijkS}, \overline{\nu}_{ijkS})$
where

$$\overline{\nu}_{ijkS} = T - T^m_{S_{ijk}} + \underline{\nu}_{ijkS}$$

and

$$\overline{s}^2_{ijkS} = \frac{\sum_{t=1}^{T}(e^S_{ijkt})^2 + \underline{\nu}_{ijkS}\underline{s}^2_{ijkS}}{\overline{\nu}_{ijkS}}$$

where $e^S_{ijkt} = S_{ijkt} - \lambda^S_{ijk}L_{kt} - \psi^S_{ij}C_t - \beta'_{ik}X_t$ if S_{ijkt} is observed, $T^m_{S_{ijk}}$ is the number of missing observations in S_{ijk}.

- **Generating λ^S_{ijk}, Conditional on S_{ijkt}, ψ^S_{ij}, β_{ik}, h_{ijkS}, L_{kt} and C_t.**

Let $S^\flat_{ijkt} = S_{ijkt} - \beta'_{ik}X_t - \psi^S_{ij}C_t$ if S_{ijkt} is observed. We transform each measurement equation into the following form:

$$S^\flat_{ijkt} = \lambda^S_{ijk}L_{kt} + \varepsilon^S_{ijkt} \tag{5}$$

Prior
$\lambda^S_{ijk} \sim N(\underline{b}_{\lambda^S_{ijk}}, \underline{V}_{\lambda^S_{ijk}})$ with $\lambda^S_{ijk} > 0$

Posterior
$\lambda^S_{ijk}|S_{ijkt}, \psi^S_{ij}, \beta_{ik}, h_{ijkS}, L_{kt}, C_t \sim N(\overline{b}_{\lambda^S_{ijk}}, \overline{V}_{\lambda^S_{ijk}})$ with $\lambda^S_{ijk} > 0$
where

$$\overline{V}_{\lambda^S_{ijk}} = \{\underline{V}^{-1}_{\lambda^S_{ijk}} + h_{ijkS}L'_kL_k\}^{-1}$$

and

$$\overline{b}_{\lambda^S_{ijk}} = \overline{V}_{\lambda^S_{ijk}}\{\underline{V}^{-1}_{\lambda^S_{ijk}}\underline{b}_{\lambda^S_{ijk}} + h_{ijkS}L'_kS^\flat_{ijk}\}$$

where $S^\flat_{ijk} = [S^\flat_{ijk1}, S^\flat_{ijk2}, ..., S^\flat_{ijkT}]'$ and $L_k = [L_{k,1}, L_{k,2}, ..., L_{kT}]'$.

- **Generating ψ^S_{ij}, Conditional on S_{ijkt}, λ^S_{ijk}, β_{ik}, h_{ijkS}, L_{kt} and C_t.**

Let $S^\natural_{ijkt} = S_{ijkt} - \lambda^S_{ijk}L_{kt} - \beta'_{ik}X_t$ if S_{ijkt} is observed. The corresponding measurement equation can be rewritten as

$$S^\natural_{ijkt} = \psi^S_{ij}C_t + \varepsilon^S_{ijkt} \tag{6}$$

Prior
$\psi^S_{ij} \sim N(\underline{b}_{\psi^S_{ij}}, \underline{V}_{\psi^S_{ij}})$ with $\psi^S_{ij} > 0$

Posterior
$\psi_{ij}^S | S_{ijkt}, \lambda_{ijk}^S, \beta_{ik}, h_{ijkS}, L_{kt}, C_t \sim N(\overline{b}_{\psi_{ij}^S}, \overline{V}_{\psi_{ij}^S})$ with $\psi_{ij}^S > 0$
where

$$\overline{V}_{\psi_{ij}^S} = \{\underline{V}_{\psi_{ij}^S}^{-1} + \sum_{k=1}^{k=K} h_{ijk} C^{'} C\}^{-1}$$

and

$$\overline{b}_{\psi_{ij}^S} = \overline{V}_{\psi_{ij}^S} \{\underline{V}_{\psi_{ij}^S}^{-1} \underline{b}_{\psi_{ij}^S} + \sum_{k=1}^{k=K} h_{ijk} C^{'} S_{ijk}^{\natural}\}$$

where $S_{ijk}^{\natural} = [S_{ijk1}^{\natural}, S_{ijk2}^{\natural}, ..., S_{ijkT}^{\natural}]^{'}$ and $C = [C_1, C_2, ..., C_T]^{'}$.

- **Generating β_{ik}, Conditional on S_{ijkt}, λ_{ijk}^S, ψ_{ij}^S, h_{ijkS}, L_{kt} and C_t.**

Let $S_{ijkt}^{\sharp} = S_{ijkt} - \lambda_{ijk}^S L_{kt} - \psi_{ij}^S C_t$ if S_{ijkt} is observed. The corresponding measurement equation can be transformed into:

$$S_{ijkt}^{\sharp} = \beta_{ik}^{'} X_t + \varepsilon_{ijkt}^S \tag{7}$$

Prior
$\beta_{ik} \sim N(\underline{b}_{\beta_{ik}}, \underline{V}_{\beta_{ik}})$

Posterior

$$\beta_{ik} | S_{ijkt}, \lambda_{ijk}^S, \psi_{ij}^S, h_{ijkS}, L_{kt}, C_t \sim N(\overline{b}_{\beta_{ik}}, \overline{V}_{\beta_{ik}})$$

where

$$\overline{V}_{\beta_{ik}} = \{\underline{V}_{\beta_{ik}}^{-1} + \sum_{j=1}^{j=J} h_{ijk} X^{'} X\}^{-1}$$

and

$$\overline{b}_{\beta_{ik}} = \overline{V}_{\beta_{ik}} \{\underline{V}_{\beta_{ik}}^{-1} \underline{b}_{\beta_{ik}} + \sum_{j=1}^{j=J} h_{ijk} X^{'} S_{ijk}^{\sharp}\}$$

where $S_{ijk}^{\sharp} = [S_{ijk1}^{\sharp}, S_{ijk2}^{\sharp}, ..., S_{ijkT}^{\sharp}]^{'}$ and $X = [X_1, X_2, ..., X_t]^{'}$.

- **Generating σ_{jD}^2, Conditional on D_{jt}, ψ_j^C, γ and C_t.**

Prior
$h_{jD} \sim G(\underline{s}_{jD}^{-2}, \underline{\nu}_{jD})$ where $h_{jD} = \sigma_{jD}^{-2}$

Posterior

$$h_{jD}|D_{jt}, \psi_j^C, \gamma, C_t \sim G(\overline{s}_{jD}^{-2}, \overline{\nu}_{jD})$$

where

$$\overline{\nu}_{jD} = T - T_{D_{jt}}^m + \underline{\nu}_{jD}$$

and

$$\overline{s}_{jD}^{-2} = \frac{\sum_{t=1}^{T}(e_{jt}^D)^2 + \underline{\nu}_{jD}\underline{s}_{jD}^2}{\overline{\nu}_{jD}}$$

where $T_{D_{jt}}^m$ is the total number of missing observations in D_j, $e_{jt}^D = D_{jt} - \psi_j^C C_t - \gamma' Z_t$ if D_{jt} is observed.

- **Generating ψ_j^C, Conditional on D_{jt}, γ, h_{jD} and C_t.**

Let $D_{jt}^\flat = D_{jt} - \gamma' Z_t$ if D_{jt} is observed. We rewrite the measurement equation for the credit default variable as:

$$D_{jt}^\flat = \psi_j^C C_t + \varepsilon_{jt}^D \tag{8}$$

Prior
$\psi_j^C \sim N(\underline{b}_{\psi_j^C}, \underline{V}_{\psi_j^C})$ with $\psi_j^C > 0$

Posterior
$\psi_j^C|D_{jt}, h_{jD}, \gamma, C_t \sim N(\overline{b}_{\psi_j^C}, \overline{V}_{\psi_j^C})$ with $\psi_j^C > 0$
where

$$\overline{V}_{\psi_j^C} = \{\underline{V}_{\psi_j^C}^{-1} + h_{jD} C' C\}^{-1}$$

and

$$\overline{b}_{\psi_j^C} = \overline{V}_{\psi_j^C}\{\underline{V}_{\psi_j^C}^{-1}\underline{b}_{\psi_j^C} + h_{jD} C' D_j^\flat\}$$

where $D_j^\flat = [D_{j1}^\flat, D_{j2}^\flat, ..., D_{jT}^\flat]'$ and $C = [C_1, C_2, ..., C_T]'$.

- **Generating γ, Conditional on D_{jt}, ψ_j^C, h_{jD} and C_t.**

Let $D_{jt}^\natural = D_{jt} - \psi_j^C C_t$ if D_{jt} is observed. We rewrite the corresponding measurement equation as:

$$D_{jt}^\natural = \gamma' Z_t + \varepsilon_{jt}^D \tag{9}$$

Prior
$\gamma \sim N(\underline{b}_\gamma, \underline{V}_\gamma)$

Posterior
$\gamma | D_{jt}, h_{jD}, \psi_j^C, C_t \sim N(\bar{b}_\gamma, \overline{V}_\gamma)$ where

$$\overline{V}_\gamma = \{\underline{V}_\gamma^{-1} + \sum_{j=1}^{j=J} h_{jD} Z' Z\}^{-1}$$

and

$$\bar{b}_\gamma = \overline{V}_\gamma \{\underline{V}_\gamma^{-1} \underline{b}_\gamma + \sum_{j=1}^{j=J} h_{jD} Z' D_j^\natural\}$$

where $D_j^\natural = [D_{j1}^\natural, D_{j2}^\natural ..., D_{jT}^\natural]'$ and $Z = [Z_1, Z_2, ..., Z_T]'$.

1.3 Draw Parameters for the Latent Risk Equations

Without loss of generality, we set $s_t^L = 0$ if s_t^L is in 'good' state for liquidity risk, and $s_t^L = 1$ if s_t^L is in 'bad' state for liquidity risk. Likewise, we set $s_t^C = 0$ if s_t^C is in 'good' state for credit risk, and $s_t^C = 1$ if s_t^C is in 'bad' state for credit risk.

For notation convenience, we rewrite the state equations as follows:

$$L_{kt} = \phi_{k00}^L + \phi_{k01}^L s_t^L + (\phi_{k10}^L + \phi_{k11}^L s_t^L) L_{k,t-1} + \sigma_{kL}(s_t^L) v_{kt}^L \tag{10}$$

$$C_t = \phi_{00}^C + \phi_{01}^C s_t^C + (\phi_{10}^C + \phi_{11}^C s_t^C) C_{t-1} + \sigma_C(s_t^C) v_t^C \tag{11}$$

where
$\phi_{k00}^L = \phi_{k0}^L(G_L)$, $\phi_{k00}^L + \phi_{k01}^L = \phi_{k0}^L(B_L)$
$\phi_{k10}^L = \phi_{k1}^L(G_L)$, $\phi_{k10}^L + \phi_{k11}^L = \phi_{k1}^L(B_L)$
and
$\phi_{00}^C = \phi_0^C(G_C)$, $\phi_{00}^C + \phi_{01}^C = \phi_0^C(B_C)$
$\phi_{10}^C = \phi_1^C(G_C)$, $\phi_{10}^C + \phi_{11}^C = \phi_1^C(B_C)$

Considering that latent risks are more volatile on average in the bad states, we define

$$\sigma_{kL}^2(B_L) = \sigma_{kL}^2(G_L)(1 + h_{kLB})$$
$$\sigma_C^2(B_C) = \sigma_C^2(G_C)(1 + h_{CB})$$

where $h_{kLB} > 0$ and $h_{CB} > 0$.

- **Generating ϕ^L_{k00}, ϕ^L_{k01}, ϕ^L_{k10}, ϕ^L_{k11}, Conditional on L_{kt} and $\sigma_{kL}(s^L_t)$.**

Dividing both sides of the state equation by $\sigma_{kL}(s^L_t)$, we have

$$L^\dagger_{kt} = \phi^L_{k00} x^\dagger_{1t} + \phi^L_{k01} x^{\dagger\dagger}_{1t} + \phi^L_{k10} x^\dagger_{2t} + \phi^L_{k11} x^{\dagger\dagger}_{2t} + v^L_{kt} \qquad (12)$$

where

$$L^\dagger_{kt} = \frac{L_{kt}}{\sigma_{kL}(s^L_t)}$$

$$x^\dagger_{1t} = \frac{1}{\sigma_{kL}(s^L_t)}$$

$$x^{\dagger\dagger}_{1t} = \frac{s^L_t}{\sigma_{kL}(s^L_t)}$$

$$x^\dagger_{2t} = \frac{L_{k,t-1}}{\sigma_{kL}(s^L_t)}$$

$$x^{\dagger\dagger}_{2t} = \frac{L_{k,t-1} s^L_t}{\sigma_{kL}(s^L_t)}$$

In matrix notation, equation (12) can be written as

$$L^\dagger_k = X^\dagger_{kL} b_{\phi_{kL}} + V_{kL} \qquad V_{kL} \sim N(0, I_T) \qquad (13)$$

where

$$X^\dagger_{kLt} = [x^\dagger_{1t}, x^{\dagger\dagger}_{1t}, x^\dagger_{2t}, x^{\dagger\dagger}_{1t}]$$

and

$$b_{\phi_{kL}} = [\phi^L_{k00}, \phi^L_{k01}, \phi^L_{k10}, \phi^L_{k11}]'$$

We assume Normal prior for $b_{\phi_{kL}}$:
Prior

$$b_{\phi_{kL}} \sim N(\underline{b}_{\phi_{kL}}, \underline{V}_{\phi_{kL}})$$

with the elements of $b_{\phi_{kL}}$ subject to the following restrictions:

$$\phi^L_{k10} \in (0,1) \qquad \phi^L_{k10} + \phi^L_{k11} \in (0,1)$$

$$\frac{\phi^L_{k00}}{1 - \phi^L_{k10}} < \frac{\phi^L_{k00} + \phi^L_{k01}}{1 - \phi^L_{k10} - \phi^L_{k11}}$$

To save space, we use $R(b_{\phi_{kL}})$ to denote these additional restrictions.

Posterior

$$b_{\phi_{kL}} \sim N(\overline{b}_{\phi_{kL}}, \overline{V}_{\phi_{kL}})R(b_{\phi_{kL}})$$

where

$$\overline{V}_{\phi_{kL}} = \{\underline{V}_{\phi_{kL}}^{-1} + (X_{kL}^{\dagger})' X_{kL}^{\dagger}\}^{-1}$$

and

$$\overline{b}_{\phi_{kL}} = \overline{V}_{\phi_{kL}} \{\underline{V}_{\phi_{kL}}^{-1} \underline{b}_{\phi_{kL}}^{-1} + (X_{kL}^{\dagger})' L_k^{\dagger}\}$$

- **Generating $\sigma_{kL}^2(G_L)$, Conditional on L_{kt}, ϕ_{k00}^L, ϕ_{k01}^L, ϕ_{k10}^L, ϕ_{k11}^L and h_{kLB}.**

To generate $\sigma_{kL}^2(G_L)$, we divide both sides of equation (10) by $\sqrt{1 + h_{kLB} s_t^L}$

$$L_{kt}^{\ddagger} = \phi_{k00}^L x_{1t}^{\ddagger} + \phi_{k01}^L x_{1t}^{\ddagger\ddagger} + \phi_{k10}^L x_{2t}^{\ddagger} + \phi_{k11}^L x_{2t}^{\ddagger\ddagger} + \sigma_{kL}(G_L) v_{kt}^L \qquad (14)$$

where

$$L_{kt}^{\ddagger} = \frac{L_{kt}}{\sqrt{1 + h_{kLB} s_t^L}}$$

$$x_{1t}^{\ddagger} = \frac{1}{\sqrt{1 + h_{kLB} s_t^L}}$$

$$x_{1t}^{\ddagger\ddagger} = \frac{s_t^L}{\sqrt{1 + h_{kLB} s_t^L}}$$

$$x_{2t}^{\ddagger} = \frac{L_{k,t-1}}{\sqrt{1 + h_{kLB} s_t^L}}$$

$$x_{2t}^{\ddagger\ddagger} = \frac{L_{k,t-1} s_t^L}{\sqrt{1 + h_{kLB} s_t^L}}$$

Prior

$$h_{kL} \sim G(\underline{s}_{kL}^{-2}, \underline{\nu}_{kL})$$

Posterior

$$h_{kL} \sim G(\overline{s}_{kL}^{-2}, \overline{\nu}_{kL})$$

where

$$\overline{\nu}_{kL} = T + \underline{\nu}_{kL}$$

and

$$\overline{s}_{kL}^2 = \frac{\underline{\nu}_{kL} \underline{s}_{kL}^2 + \sum_{t=1}^{t=T} (L_{kt}^{\ddagger} - \phi_{k00}^L x_{1t}^{\ddagger} - \phi_{k01}^L x_{1t}^{\ddagger\ddagger} - \phi_{k10}^L x_{2t}^{\ddagger} - \phi_{k11}^L x_{2t}^{\ddagger\ddagger})^2}{\overline{\nu}_{kL}}$$

Given h_{kL}, we can derive $\sigma_{kL}(G_L)$ by $\sigma_{kL}(G_L) = \frac{1}{\sqrt{h_{kL}}}$.

- **Generating h_{kLB}, Conditional on L_{kt}, ϕ^L_{k00}, ϕ^L_{k01}, ϕ^L_{k10}, ϕ^L_{k11} and $\sigma_{kL}(G_L)$.**

To draw h_{kLB}, we divide both sides of equation (10) by $\sigma_{kL}(G_L)$:

$$L^{\S}_{kt} = \phi^L_{k00}x^{\S}_{1t} + \phi^L_{k01}x^{\S\S}_{1t} + \phi^L_{k10}x^{\S}_{2t} + \phi^L_{k11}x^{\S\S}_{2t} + v^L_{kt}\sqrt{1 + h_{kLB}s^L_t} \tag{15}$$

where

$$L^{\S}_{kt} = \frac{L_{kt}}{\sigma_{kL}(G_L)}$$

$$x^{\S}_{1t} = \frac{1}{\sigma_{kL}(G_L)}$$

$$x^{\S\S}_{1t} = \frac{s^L_t}{\sigma_{kL}(G_L)}$$

$$x^{\S}_{2t} = \frac{L_{k,t-1}}{\sigma_{kL}(G_L)}$$

$$x^{\S\S}_{2t} = \frac{L_{k,t-1}s^L_t}{\sigma_{kL}(G_L)}$$

Let $h^{\S}_{kLB} = \frac{1}{1+h_{kLB}}$, we set Gamma prior for $h^{\S}_{kLB}$:

Prior

$$h^{\S}_{kLB} \sim G(\underline{s}^{-2}_{kL^{\S}}, \underline{\nu}_{kL^{\S}})$$

subject to the restriction that $h^{\S}_{kLB} < 1$.

Posterior

$$h^{\S}_{kLB} \sim G(\overline{s}^{-2}_{kL^{\S}}, \overline{\nu}_{kL^{\S}})$$

subject to the restriction that $h^{\S}_{kLB} < 1$.
where

$$\overline{\nu}_{kL^{\S}} = \underline{\nu}_{kL^{\S}} + T^{\S}$$

$$\overline{s}^2_{kL^{\S}} = \frac{\underline{\nu}_{kL^{\S}}\underline{s}^2_{kL^{\S}} + \sum^{T^{\S}}(L^{\S}_{kt} - \phi^L_{k00}x^{\S}_{1t} - \phi^L_{k01}x^{\S\S}_{1t} - \phi^L_{k10}x^{\S}_{2t} - \phi^L_{k11}x^{\S\S}_{2t})^2}{\overline{\nu}_{kL^{\S}}}$$

Note that $T^{\S} = \{t : s^L_t = 1\}$, also $h^{\S}_{kLB}$ depends only on the values of $L^{\S}_{kt}$ for which $s^L_t = 1$.

Once $h^{\S}_{kLB}$ is drawn from the above posterior, we can calculate h_{kLB} by $h_{kLB} = \frac{1}{h^{\S}_{kLB}} - 1$.

- **Generating ϕ^C_{00}, ϕ^C_{01}, ϕ^C_{10}, ϕ^C_{11}, Conditional on $\sigma_C(s^C_t)$ and C_t.**

Dividing both sides of equation (11) by $\sigma_C(s_t^C)$, we have

$$C_t^\dagger = \phi_{00}^C z_{1t}^\dagger + \phi_{01}^C z_{1t}^{\dagger\dagger} + \phi_{10}^C z_{2t}^\dagger + \phi_{11}^C z_{2t}^{\dagger\dagger} + v_t^C \tag{16}$$

where

$$C_t^\dagger = \frac{C_t}{\sigma_C(s_t^C)}$$

$$z_{1t}^\dagger = \frac{1}{\sigma_C(s_t^C)}$$

$$z_{1t}^{\dagger\dagger} = \frac{s_t^C}{\sigma_C(s_t^C)}$$

$$z_{2t}^\dagger = \frac{C_{t-1}}{\sigma_C(s_t^C)}$$

$$z_{2t}^{\dagger\dagger} = \frac{C_{t-1}s_t^C}{\sigma_C(s_t^C)}$$

In matrix notation, equation (12) can be written as

$$C^\dagger = Z_C^\dagger b_{\phi_C} + V_C \qquad V_C \sim N(0, I_T) \tag{17}$$

where

$$Z_{Ct}^\dagger = [z_{1t}^\dagger, z_{1t}^{\dagger\dagger}, z_{2t}^\dagger, z_{1t}^{\dagger\dagger}]$$

and

$$b_{\phi_C} = [\phi_{00}^C, \phi_{01}^C, \phi_{10}^C, \phi_{11}^C]'$$

We assume Normal prior for b_{ϕ_C}:

Prior

$$b_{\phi_C} \sim N(\underline{b}_{\phi_C}, \underline{V}_{\phi_C})$$

with the elements of b_{ϕ_C} subject to the following restrictions:

$$\phi_{10}^C \in (0,1) \qquad \phi_{10}^C + \phi_{11}^C \in (0,1)$$

$$\frac{\phi_{00}^C}{1-\phi_{10}^C} < \frac{\phi_{00}^C + \phi_{01}^C}{1-\phi_{10}^C-\phi_{11}^C}$$

To save space, we use $R(b_{\phi_C})$ to denote these additional restrictions.

Posterior

$$b_{\phi_C} \sim N(\overline{b}_{\phi_C}, \overline{V}_{\phi_C})R(b_{\phi_C})$$

where

$$\overline{V}_{\phi_C} = \{\underline{V}_{\phi_C}^{-1} + (Z_C^\dagger)' Z_C^\dagger\}^{-1}$$

and

$$\overline{b}_{\phi_C} = \overline{V}_{\phi_C}\{\underline{V}_{\phi_C}^{-1}\underline{b}_{\phi_C}^{-1} + (Z_C^\dagger)' C^\dagger\}$$

- **Generating $\sigma_C^2(G_C)$, Conditional on C_t, ϕ_{00}^C, ϕ_{01}^C, ϕ_{10}^C, ϕ_{11}^C and h_{CB}.**

To generate $\sigma_C^2(G_C)$, we divide both sides of equation (11) by $\sqrt{1+h_{CB}s_t^C}$

$$C_t^{\ddagger} = \phi_{00}^C z_{1t}^{\ddagger} + \phi_{01}^C z_{1t}^{\ddagger\ddagger} + \phi_{10}^C z_{2t}^{\ddagger} + \phi_{11}^C z_{2t}^{\ddagger\ddagger} + \sigma_C(G_C)v_t^C \tag{18}$$

where

$$C_t^{\ddagger} = \frac{C_t}{\sqrt{1+h_{CB}s_t^C}}$$

$$z_{1t}^{\ddagger} = \frac{1}{\sqrt{1+h_{CB}s_t^C}}$$

$$z_{1t}^{\ddagger\ddagger} = \frac{s_t^C}{\sqrt{1+h_{CB}s_t^C}}$$

$$z_{2t}^{\ddagger} = \frac{C_{t-1}}{\sqrt{1+h_{CB}s_t^C}}$$

$$z_{2t}^{\ddagger\ddagger} = \frac{C_{t-1}s_t^C}{\sqrt{1+h_{CB}s_t^C}}$$

Prior

$h_C \sim G(\underline{s}_C^{-2}, \underline{\nu}_C)$ where $h_C = \sigma_C^{-2}(G_C)$

Posterior

$$h_C \sim G(\overline{s}_C^{-2}, \overline{\nu}_C)$$

where

$$\overline{\nu}_C = T + \underline{\nu}_C$$

and

$$\overline{s}_C^2 = \frac{\underline{\nu}_C \underline{s}_C^2 + \sum_{t=1}^{t=T}(C_t^{\ddagger} - \phi_{00}^C z_{1t}^{\ddagger} - \phi_{01}^C z_{1t}^{\ddagger\ddagger} - \phi_{10}^C z_{2t}^{\ddagger} - \phi_{11}^C z_{2t}^{\ddagger\ddagger})^2}{\overline{\nu}_C}$$

Given h_C, we can derive $\sigma_C(G_C)$ by $\sigma_C(G_C) = \frac{1}{\sqrt{h_C}}$.

- **Generating h_{CB}, Conditional on C_t, ϕ_{00}^C, ϕ_{01}^C, ϕ_{10}^C, ϕ_{11}^C and $\sigma_C(G_C)$.**

To draw h_{CB}, we divide both sides of equation (11) by $\sigma_C(G_C)$:

$$C_t^{\S} = \phi_{00}^C z_{1t}^{\S} + \phi_{01}^C z_{1t}^{\S\S} + \phi_{10}^C z_{2t}^{\S} + \phi_{11}^C z_{2t}^{\S\S} + v_t^C \sqrt{1 + h_{CB} s_t^C} \tag{19}$$

where

$$C_t^{\S} = \frac{C_t}{\sigma_C(G_C)}$$

$$z_{1t}^{\S} = \frac{1}{\sigma_C(G_C)}$$

$$z_{1t}^{\S\S} = \frac{s_t^C}{\sigma_C(G_C)}$$

$$z_{2t}^{\S} = \frac{C_{t-1}}{\sigma_C(G_C)}$$

$$z_{2t}^{\S\S} = \frac{C_{t-1} s_t^C}{\sigma_C(G_C)}$$

Let $h_{CB}^{\S} = \frac{1}{1+h_{CB}}$, we set Gamma prior for $h_{CB}^{\S}$:

Prior

$$h_{CB}^{\S} \sim G(\underline{s}_{C^{\S}}^{-2}, \underline{\nu}_{C^{\S}})$$

subject to the restriction that $h_{CB}^{\S} < 1$.

Posterior

$$h_{CB}^{\S} \sim G(\overline{s}_{C^{\S}}^{-2}, \overline{\nu}_{C^{\S}})$$

subject to the restriction that $h_{CB}^{\S} < 1$.
where

$$\overline{\nu}_{C^{\S}} = \underline{\nu}_{C^{\S}} + T_C^{\S}$$

$$\overline{s}_{C^{\S}}^2 = \frac{\underline{\nu}_{C^{\S}} \underline{s}_{C^{\S}}^2 + \sum^{T_C^{\S}} (C_t^{\S} - \phi_{00}^C z_{1t}^{\S} - \phi_{01}^C z_{1t}^{\S\S} - \phi_{10}^C z_{2t}^{\S} - \phi_{11}^C z_{2t}^{\S\S})^2}{\overline{\nu}_{C^{\S}}}$$

Note that $T_C^{\S} = \{t : s_t^C = 1\}$, and $h_{CB}^{\S}$ depends only on the values of $C_t^{\S}$ for which $s_t^C = 1$.

Once $h_{CB}^{\S}$ is drawn from the above posterior, h_{CB} can be calculated by $h_{CB} = \frac{1}{h_{CB}^{\S}} - 1$.

1.4 Generating s_t^L, s_t^C and M

- **Generate s_t^L and s_t^C, Conditional on M, L_{kt}, C_t and the other model parameters**

We use the multimove Gibbs-sampling method described in Kim and Nelson (1999, Ch 9) to draw the latent Markov-Switching states.

To summarize, we first run Hamilton's (1989) filter to get the probability $f(s_t|\widetilde{L}_{kt}, \widetilde{C}_t)$ for $t = 1, 2, ..., T$ and save them, where $\widetilde{L}_{kt} = [L_{k1}, L_{k2}, ..., L_{kt}]'$ and $\widetilde{C}_t = [C_1, C_2, ..., C_t]'$. Then we generate s_T from the last iteration of the filter. After that, we recursively generate s_t conditional on $\widetilde{L}_{kt}$, $\widetilde{C}_t$ and s_{t+1} for $t = T-1, T-2, ...1$.

- **Generate M, Conditional on s_t^L, s_t^C, L_{kt}, C_t and the other model parameters**

As explained in Chib (1996), given $\widetilde{s}_T$, the posterior distribution of the transition matrix M can be derived without regard to the sampling model.

Let vector m_b be the b^{th} column of M. We elicit a Dirichlet prior for m_b:

$$m_b \sim D(\alpha_{1,b}, \alpha_{2,b}, ..., \alpha_{a,b})$$

Thus, the posterior for m_b is:

$$m_b|\widetilde{s}_T \sim D(\alpha_{1,b} + q_{1,b}, \alpha_{2,b} + q_{2,b}, ..., \alpha_{a,b} + q_{a,b})$$

where $q_{a,b}$ is the number of transitions from $s_t = b$ to $s_{t+1} = a$ in the vector $\widetilde{s}_T$.

2 Priors and Prior Sensitivity Analysis

2.1 Elicited Priors

The results presented in the paper involve the following priors:

$\underline{s}_{ijkS}^{-2} = 10, \quad \underline{\nu}_{ijkS} = 0.1$
$\underline{b}_{\lambda_{ijk}^S} = 1, \quad \underline{V}_{\lambda_{ijk}^S} = 10$
$\underline{b}_{\psi_{ij}^S} = 1, \quad \underline{V}_{\psi_{ij}^S} = 10$
$\underline{b}_{\gamma} = 0, \quad \underline{V}_{\gamma} = 10$
$\underline{b}_{\beta_{ik}} = 0, \quad \underline{V}_{\beta_{ik}} = 10$
$\underline{s}_{jD}^{-2} = 10, \quad \underline{\nu}_{jD} = 0.1$

$\underline{b}_{\psi_j^C} = 1, \quad \underline{V}_{\psi_j^C} = 10$
$\underline{b}_{\phi_{kL}} = 0_{4\times 1}, \quad \underline{V}_{\phi_{kL}} = 10 * I_4$
$\underline{s}_{kL}^{-2} = 10, \quad \underline{\nu}_{kL} = 0.1$
$\underline{s}_{kL^\S}^{-2} = 0.1, \quad \underline{\nu}_{kL^\S} = 10$
$\underline{b}_{\phi_C} = 0_{4\times 1}, \quad \underline{V}_{\phi_C} = 10 * I_4$
$\underline{s}_{C}^{-2} = 10, \quad \underline{\nu}_{C} = 0.1$
$\underline{s}_{C^\S}^{-2} = 0.1, \quad \underline{\nu}_{C^\S} = 10$
$\alpha_{a,b} = 1$ for $a, b \in \{1, 2, 3, 4\}$.

2.2 Prior Sensitivity Analysis

The following priors are used for prior sensitivity analysis.
$\underline{s}_{ijkS}^{-2} = 1, \quad \underline{\nu}_{ijkS} = 1$
$\underline{b}_{\lambda_{ijk}^S} = 0, \quad \underline{V}_{\lambda_{ijk}^S} = 100$
$\underline{b}_{\psi_{ij}^S} = 0, \quad \underline{V}_{\psi_{ij}^S} = 100$
$\underline{b}_{\gamma} = 0, \quad \underline{V}_{\gamma} = 100$
$\underline{b}_{\beta_{ik}} = 0, \quad \underline{V}_{\beta_{ik}} = 100$
$\underline{s}_{jD}^{-2} = 1, \quad \underline{\nu}_{jD} = 1$
$\underline{b}_{\psi_j^C} = 1, \quad \underline{V}_{\psi_j^C} = 100$
$\underline{b}_{\phi_{kL}} = 0_{4\times 1}, \quad \underline{V}_{\phi_{kL}} = 4 * I_4$
$\underline{s}_{kL}^{-2} = 1, \quad \underline{\nu}_{kL} = 1$
$\underline{s}_{kL^\S}^{-2} = 0.1, \quad \underline{\nu}_{kL^\S} = 10$
$\underline{b}_{\phi_C} = 0_{4\times 1}, \quad \underline{V}_{\phi_C} = 4 * I_4$
$\underline{s}_{C}^{-2} = 1, \quad \underline{\nu}_{C} = 1$
$\underline{s}_{C^\S}^{-2} = 0.1, \quad \underline{\nu}_{C^\S} = 10$
$\alpha_{a,b} = 2$ for $a, b \in \{1, 2, 3, 4\}$.
Empirical results using these new priors are as follows.

Table 1: Model Comparison

	BIC	AIC
Model A	-2.802	-3.901
Model B	-2.492	-3.565
Model C	-2.664	-3.737
Model D	-2.321	-3.369
Model E	-2.909	-3.932
Model F	-2.601	-3.617
Model G	-2.744	-3.760
Model H	-2.386	-3.396

Table 2: Posterior Mean of Transition Probabilities
(Posterior standard deviations in parentheses)

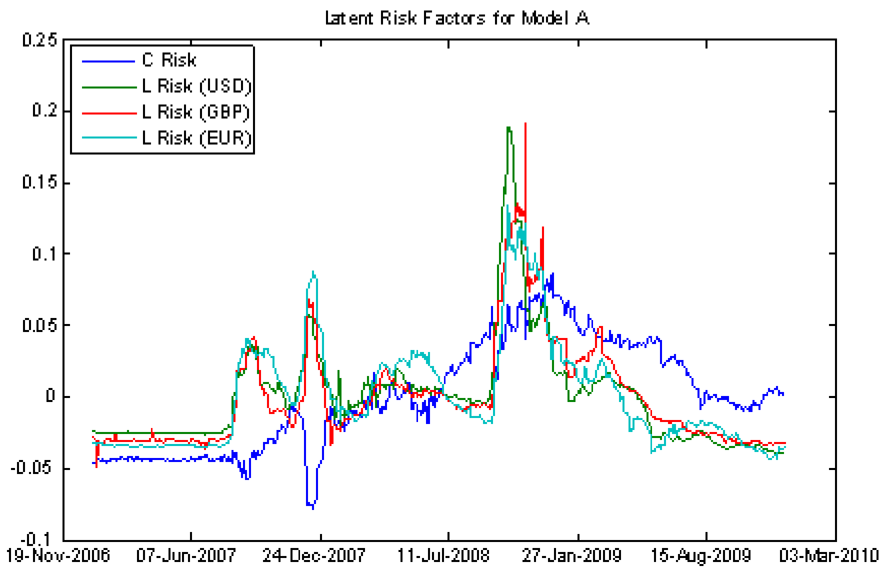
	(G_L, G_C)	(B_L, G_C)	(G_L, B_C)	(B_L, B_C)
(G_L, G_C)	0.972 (0.007)	0.231 (0.127)	0.246 (0.132)	0.221 (0.096)
(B_L, G_C)	0.009 (0.005)	0.258 (0.140)	0.235 (0.132)	0.198 (0.111)
(G_L, B_C)	0.009 (0.005)	0.187 (0.113)	0.251 (0.128)	0.149 (0.087)
(B_L, B_C)	0.010 (0.005)	0.324 (0.150)	0.267 (0.142)	0.432 (0.145)

Table 3: Proportion of Variance of Spreads Attributable to Each Component (USD)							
	var(L)	var (C)	var(X)	cov(L,C)	cov(L,X)	cov(C,X)	var(e)
$barclays_{1m}$	0.8918	0.0000	0.0008	0.0000	0.0020	0.0000	0.1054
$barclays_{3m}$	0.8208	0.0720	0.0000	0.0966	-0.0002	0.0000	0.0108
$barclays_{12m}$	0.2720	0.4217	0.0000	0.1345	0.0000	0.0000	0.1718
$btmufj_{1m}$	0.8755	0.0042	0.0011	0.0239	0.0023	0.0000	0.0930
$btmufj_{3m}$	0.7801	0.1027	0.0000	0.1125	-0.0003	0.0000	0.0050
$btmufj_{12m}$	0.2129	0.5345	0.0000	0.1340	0.0000	0.0000	0.1186
$citibank_{1m}$	0.8963	0.0015	0.0013	0.0146	0.0025	0.0000	0.0836
$citibank_{3m}$	0.7715	0.1101	0.0000	0.1158	-0.0003	0.0000	0.0029
$citibank_{12m}$	0.1991	0.5585	0.0000	0.1325	0.0000	0.0000	0.1099
$deutschebank_{1m}$	0.9094	0.0000	0.0014	0.0002	0.0026	0.0000	0.0864
$deutschebank_{3m}$	0.7876	0.0982	0.0000	0.1106	-0.0003	0.0000	0.0039
$deutschebank_{12m}$	0.2908	0.4672	0.0000	0.1465	0.0000	0.0000	0.0956
$hbos_{1m}$	0.8682	0.0000	0.0009	0.0001	0.0020	0.0000	0.1287
$hbos_{3m}$	0.8352	0.0038	0.0000	0.0221	-0.0002	0.0000	0.1391
$hbos_{12m}$	0.6070	0.0496	0.0000	0.0688	0.0000	0.0000	0.2747
$hsbc_{1m}$	0.9085	0.0001	0.0013	0.0028	0.0025	0.0000	0.0848
$hsbc_{3m}$	0.7876	0.0992	0.0000	0.1111	-0.0003	0.0000	0.0024
$hsbc_{12m}$	0.2660	0.4843	0.0000	0.1426	0.0000	0.0000	0.1070
$jpmc_{1m}$	0.9009	0.0000	0.0015	0.0003	0.0027	0.0000	0.0946
$jpmc_{3m}$	0.7692	0.1076	0.0000	0.1144	-0.0003	0.0000	0.0091
$jpmc_{12m}$	0.1849	0.5484	0.0000	0.1265	0.0000	0.0000	0.1403
$lloyds_{1m}$	0.9186	0.0000	0.0013	0.0005	0.0026	0.0000	0.0770
$lloyds_{3m}$	0.7716	0.1103	0.0000	0.1160	-0.0003	0.0000	0.0024
$lloyds_{12m}$	0.1903	0.5624	0.0000	0.1300	0.0000	0.0000	0.1173
$rabobank_{1m}$	0.8999	0.0006	0.0015	0.0089	0.0027	0.0000	0.0864
$rabobank_{3m}$	0.7460	0.1237	0.0000	0.1208	-0.0003	0.0000	0.0098
$rabobank_{12m}$	0.2110	0.5224	0.0000	0.1319	0.0000	0.0000	0.1346
$rboscotland_{1m}$	0.9163	0.0001	0.0012	0.0036	0.0024	0.0000	0.0764
$rboscotland_{3m}$	0.7686	0.1099	0.0000	0.1155	-0.0003	0.0000	0.0062
$rboscotland_{12m}$	0.1867	0.5159	0.0000	0.1233	0.0000	0.0000	0.1741
ubs_{1m}	0.9148	0.0001	0.0012	0.0045	0.0024	0.0000	0.0769
ubs_{3m}	0.7560	0.1217	0.0000	0.1206	-0.0003	0.0000	0.0021
ubs_{12m}	0.1929	0.5353	0.0000	0.1276	0.0000	0.0000	0.1441
$westlb_{1m}$	0.8708	0.0015	0.0013	0.0145	0.0024	0.0000	0.1095
$westlb_{3m}$	0.7369	0.1307	0.0000	0.1234	-0.0003	0.0000	0.0093
$westlb_{12m}$	0.1818	0.5561	0.0000	0.1263	0.0000	0.0000	0.1358

Table 4: Proportion of Variance of Spreads Attributable to Each Component (GBP)							
	var(L)	var (C)	var(X)	cov(L,C)	cov(L,X)	cov(C,X)	var(e)
$barclays_{1m}$	0.9964	0.0000	0.0000	0.0000	0.0000	0.0000	0.0036
$barclays_{3m}$	0.6936	0.1117	0.0000	0.1493	0.0000	0.0000	0.0454
$barclays_{12m}$	0.3393	0.4224	0.0000	0.2031	0.0000	0.0000	0.0352
$btmufj_{1m}$	0.9363	0.0081	0.0000	0.0466	0.0000	0.0000	0.0091
$btmufj_{3m}$	0.6632	0.1297	0.0000	0.1574	0.0000	0.0000	0.0497
$btmufj_{12m}$	0.4042	0.3832	0.0000	0.2112	0.0000	0.0000	0.0013
$citibank_{1m}$	0.9627	0.0025	0.0000	0.0263	0.0000	0.0000	0.0084
$citibank_{3m}$	0.6614	0.1204	0.0000	0.1515	0.0000	0.0000	0.0668
$citibank_{12m}$	0.3860	0.4004	0.0000	0.2110	0.0000	0.0000	0.0027
$deutschebank_{1m}$	0.9893	0.0000	0.0000	0.0004	0.0000	0.0000	0.0103
$deutschebank_{3m}$	0.6811	0.1194	0.0000	0.1530	0.0000	0.0000	0.0464
$deutschebank_{12m}$	0.4663	0.3144	0.0000	0.2055	0.0000	0.0000	0.0138
$hbos_{1m}$	0.8170	0.0000	0.0000	0.0003	0.0000	0.0000	0.1828
$hbos_{3m}$	0.6717	0.0046	0.0000	0.0295	0.0000	0.0000	0.2943
$hbos_{12m}$	0.5569	0.0366	0.0000	0.0764	0.0000	0.0000	0.3301
$hsbc_{1m}$	0.9705	0.0001	0.0000	0.0057	0.0000	0.0000	0.0236
$hsbc_{3m}$	0.6560	0.1306	0.0000	0.1571	0.0000	0.0000	0.0563
$hsbc_{12m}$	0.4222	0.3599	0.0000	0.2092	0.0000	0.0000	0.0087
$jpmc_{1m}$	0.9895	0.0000	0.0000	0.0005	0.0000	0.0000	0.0099
$jpmc_{3m}$	0.6919	0.1078	0.0000	0.1465	0.0000	0.0000	0.0538
$jpmc_{12m}$	0.4497	0.3364	0.0000	0.2087	0.0000	0.0000	0.0052
$lloyds_{1m}$	0.9978	0.0000	0.0000	0.0009	0.0000	0.0000	0.0012
$lloyds_{3m}$	0.6791	0.1208	0.0000	0.1537	0.0000	0.0000	0.0465
$lloyds_{12m}$	0.3867	0.4010	0.0000	0.2113	0.0000	0.0000	0.0010
$rabobank_{1m}$	0.9702	0.0008	0.0000	0.0149	0.0000	0.0000	0.0141
$rabobank_{3m}$	0.6683	0.1207	0.0000	0.1524	0.0000	0.0000	0.0587
$rabobank_{12m}$	0.4470	0.3355	0.0000	0.2078	0.0000	0.0000	0.0097
$rboscotland_{1m}$	0.9907	0.0002	0.0000	0.0067	0.0000	0.0000	0.0024
$rboscotland_{3m}$	0.6555	0.1367	0.0000	0.1606	0.0000	0.0000	0.0471
$rboscotland_{12m}$	0.3503	0.4340	0.0000	0.2093	0.0000	0.0000	0.0064
ubs_{1m}	0.9861	0.0003	0.0000	0.0084	0.0000	0.0000	0.0052
ubs_{3m}	0.6411	0.1411	0.0000	0.1614	0.0000	0.0000	0.0564
ubs_{12m}	0.4013	0.3863	0.0000	0.2113	0.0000	0.0000	0.0011
$westlb_{1m}$	0.9665	0.0025	0.0000	0.0265	0.0000	0.0000	0.0045
$westlb_{3m}$	0.6500	0.1459	0.0000	0.1653	0.0000	0.0000	0.0388
$westlb_{12m}$	0.3917	0.3959	0.0000	0.2113	0.0000	0.0000	0.0011

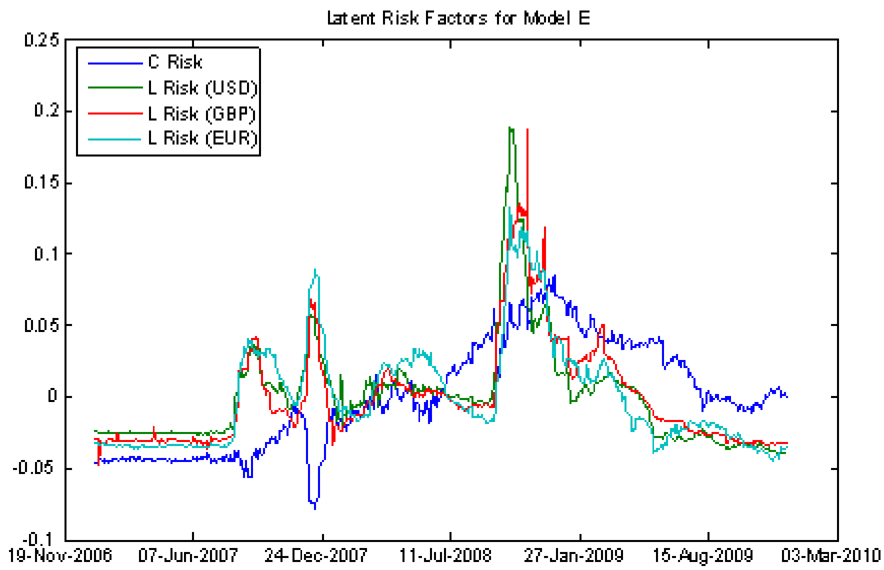
Table 5: Proportion of Variance of Spreads Attributable to Each Component (EUR)

	var(L)	var (C)	var(X)	cov(L,C)	cov(L,X)	cov(C,X)	var(e)
$barclays_{1m}$	0.8953	0.0000	0.0000	0.0000	0.0000	0.0000	0.1047
$barclays_{3m}$	0.6521	0.1986	0.0000	0.1391	0.0000	0.0000	0.0101
$barclays_{12m}$	0.2183	0.5940	0.0000	0.1392	0.0000	0.0000	0.0485
$btmufj_{1m}$	0.8509	0.0154	0.0000	0.0441	0.0000	0.0000	0.0896
$btmufj_{3m}$	0.6115	0.2391	0.0000	0.1478	0.0000	0.0000	0.0015
$btmufj_{12m}$	0.2308	0.5804	0.0000	0.1415	0.0000	0.0000	0.0474
$citibank_{1m}$	0.8573	0.0045	0.0000	0.0240	0.0000	0.0000	0.1142
$citibank_{3m}$	0.6327	0.2208	0.0000	0.1445	0.0000	0.0000	0.0020
$citibank_{12m}$	0.2288	0.5784	0.0000	0.1406	0.0000	0.0000	0.0522
$deutschebank_{1m}$	0.8600	0.0000	0.0000	0.0004	0.0000	0.0000	0.1396
$deutschebank_{3m}$	0.5914	0.2377	0.0000	0.1449	0.0000	0.0000	0.0260
$deutschebank_{12m}$	0.2786	0.5370	0.0000	0.1495	0.0000	0.0000	0.0348
$hbos_{1m}$	0.8276	0.0000	0.0000	0.0003	0.0000	0.0000	0.1721
$hbos_{3m}$	0.7510	0.0077	0.0000	0.0290	0.0000	0.0000	0.2123
$hbos_{12m}$	0.5575	0.0610	0.0000	0.0711	0.0000	0.0000	0.3104
$hsbc_{1m}$	0.8616	0.0003	0.0000	0.0051	0.0000	0.0000	0.1330
$hsbc_{3m}$	0.6458	0.2079	0.0000	0.1416	0.0000	0.0000	0.0047
$hsbc_{12m}$	0.2908	0.5170	0.0000	0.1499	0.0000	0.0000	0.0423
$jpmc_{1m}$	0.9018	0.0000	0.0000	0.0005	0.0000	0.0000	0.0977
$jpmc_{3m}$	0.6562	0.2013	0.0000	0.1405	0.0000	0.0000	0.0020
$jpmc_{12m}$	0.2787	0.5280	0.0000	0.1483	0.0000	0.0000	0.0450
$lloyds_{1m}$	0.8918	0.0000	0.0000	0.0009	0.0000	0.0000	0.1073
$lloyds_{3m}$	0.6309	0.2220	0.0000	0.1447	0.0000	0.0000	0.0024
$lloyds_{12m}$	0.2037	0.6015	0.0000	0.1353	0.0000	0.0000	0.0595
$rabobank_{1m}$	0.8816	0.0015	0.0000	0.0137	0.0000	0.0000	0.1032
$rabobank_{3m}$	0.6043	0.2301	0.0000	0.1442	0.0000	0.0000	0.0214
$rabobank_{12m}$	0.2736	0.5323	0.0000	0.1475	0.0000	0.0000	0.0467
$rboscotland_{1m}$	0.8773	0.0003	0.0000	0.0060	0.0000	0.0000	0.1164
$rboscotland_{3m}$	0.6107	0.2350	0.0000	0.1465	0.0000	0.0000	0.0078
$rboscotland_{12m}$	0.1847	0.6213	0.0000	0.1309	0.0000	0.0000	0.0630
ubs_{1m}	0.8353	0.0005	0.0000	0.0078	0.0000	0.0000	0.1564
ubs_{3m}	0.5832	0.2578	0.0000	0.1499	0.0000	0.0000	0.0091
ubs_{12m}	0.2277	0.5860	0.0000	0.1412	0.0000	0.0000	0.0451
$westlb_{1m}$	0.8539	0.0043	0.0000	0.0234	0.0000	0.0000	0.1184
$westlb_{3m}$	0.5929	0.2518	0.0000	0.1494	0.0000	0.0000	0.0059
$westlb_{12m}$	0.2337	0.5835	0.0000	0.1427	0.0000	0.0000	0.0400



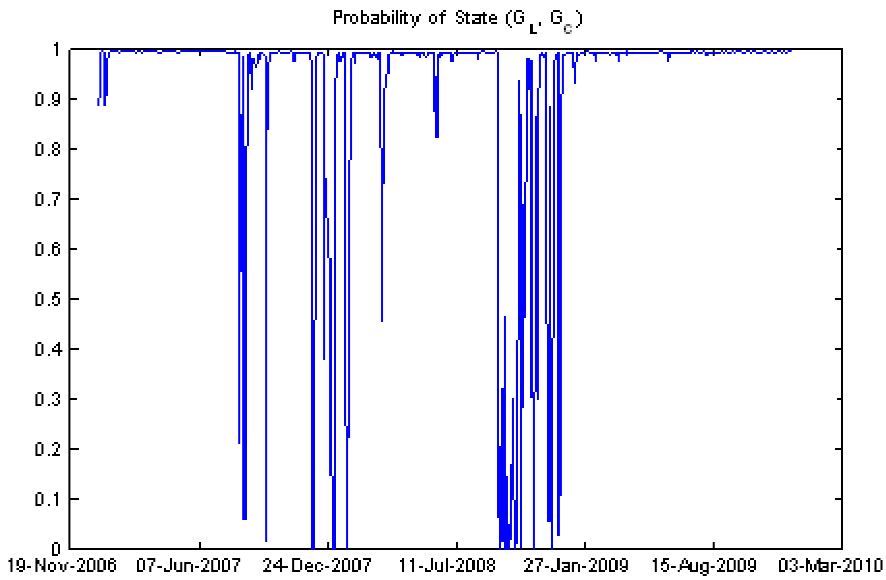
Latent Risk Factors for Model A
C Risk
L Risk (USD)
L Risk (GBP)
L Risk (EUR)
0.25
0.2
0.15
0.1
0.05
0
-0.05
-0.1
19-Nov-2006
07-Jun-2007
24-Dec-2007
11-Jul-2008
27-Jan-2009
15-Aug-2009
03-Mar-2010

Figure 1



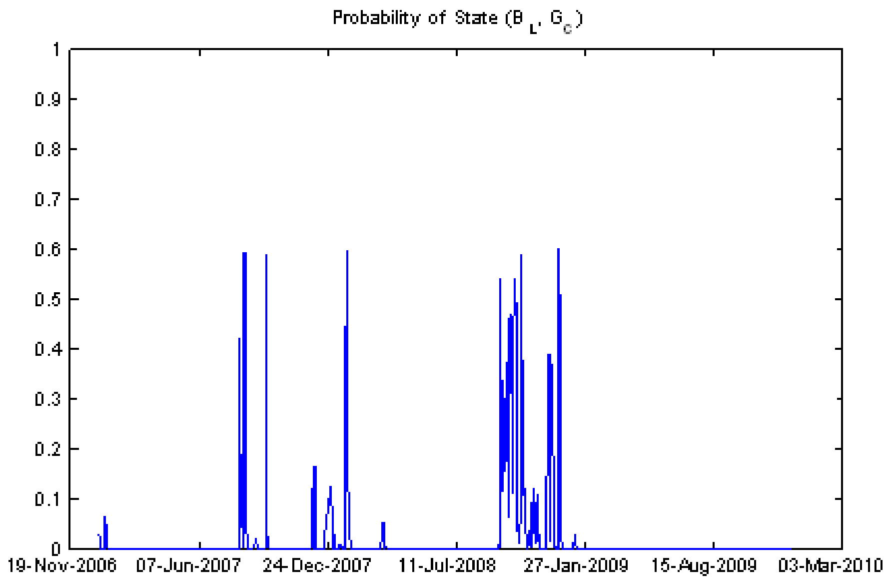
Latent Risk Factors for Model E
C Risk
L Risk (USD)
L Risk (GBP)
L Risk (EUR)
0.25
0.2
0.15
0.1
0.05
0
-0.05
-0.1
19-Nov-2006
07-Jun-2007
24-Dec-2007
11-Jul-2008
27-Jan-2009
15-Aug-2009
03-Mar-2010

Figure 2



Probability of State (G_L, G_C)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
19-Nov-2006
07-Jun-2007
24-Dec-2007
11-Jul-2008
27-Jan-2009
15-Aug-2009
03-Mar-2010

Figure 3



Probability of State (B_L, G_C)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
19-Nov-2006
07-Jun-2007
24-Dec-2007
11-Jul-2008
27-Jan-2009
15-Aug-2009
03-Mar-2010

Figure 4

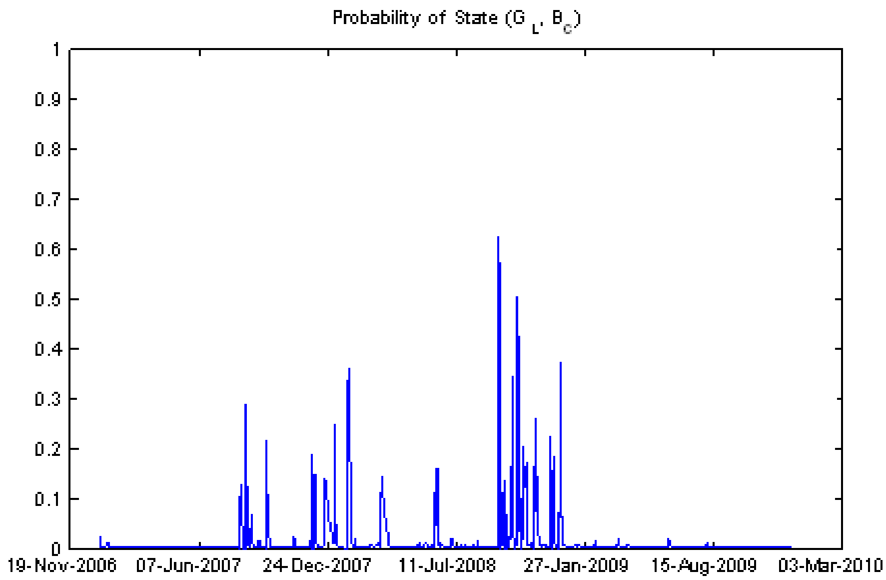

Probability of State (G L, B C)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
19-Nov-2006
07-Jun-2007
24-Dec-2007
11-Jul-2008
27-Jan-2009
15-Aug-2009
03-Mar-2010

Figure 5

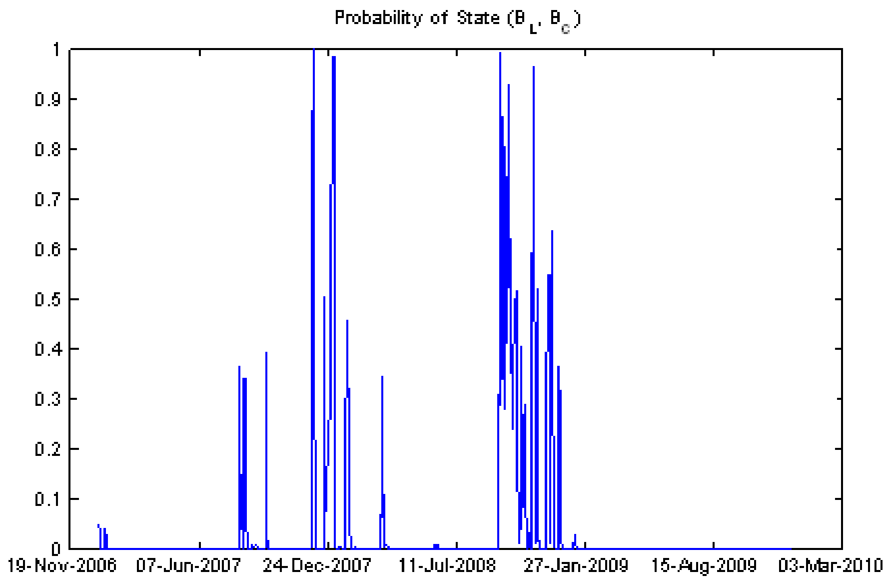


Figure 6

3 Empirical Results Involving Only Eight Banks

Empirical results reported in this section using data of the eight banks for which we do not have any missing observations.

Table 6: Model Comparison

	BIC	AIC
Model A	-3.227	-4.325
Model B	-2.853	-3.926
Model C	-3.013	-4.086
Model D	-2.593	-3.641
Model E	-3.273	-4.296
Model F	-2.886	-3.902
Model G	-3.093	-4.109
Model H	-2.620	-3.630

Table 7: Posterior Mean of Transition Probabilities (Posterior standard deviations in parentheses)				
	(G_L, G_C)	(B_L, G_C)	(G_L, B_C)	(B_L, B_C)
(G_L, G_C)	0.950 (0.013)	0.311 (0.134)	0.179 (0.093)	0.047 (0.038)
(B_L, G_C)	0.019 (0.009)	0.375 (0.149)	0.061 (0.054)	0.069 (0.062)
(G_L, B_C)	0.018 (0.010)	0.109 (0.096)	0.658 (0.108)	0.107 (0.050)
(B_L, B_C)	0.013 (0.008)	0.205 (0.141)	0.101 (0.063)	0.777 (0.077)

Table 8: Proportion of Variance of Spreads Attributable to Each Component (USD)							
	var(L)	var (C)	var(X)	cov(L,C)	cov(L,X)	cov(C,X)	var(e)
$barclays_{1m}$	0.8977	0.0000	0.0008	0.0000	0.0019	0.0000	0.0996
$barclays_{3m}$	0.7277	0.1088	0.0000	0.1521	-0.0002	0.0000	0.0117
$barclays_{12m}$	0.1120	0.6091	0.0000	0.1409	0.0000	0.0000	0.1380
$citibank_{1m}$	0.9021	0.0011	0.0013	0.0172	0.0024	0.0000	0.0758
$citibank_{3m}$	0.6746	0.1506	0.0000	0.1723	-0.0002	0.0000	0.0027
$citibank_{12m}$	0.0620	0.7329	0.0000	0.1150	0.0000	0.0000	0.0901
$deutschebank_{1m}$	0.9155	0.0000	0.0014	0.0004	0.0025	0.0000	0.0803
$deutschebank_{3m}$	0.7000	0.1319	0.0000	0.1642	-0.0002	0.0000	0.0041
$deutschebank_{12m}$	0.1412	0.6161	0.0000	0.1593	0.0000	0.0000	0.0835
$jpmc_{1m}$	0.9095	0.0000	0.0015	0.0006	0.0026	0.0000	0.0859
$jpmc_{3m}$	0.7100	0.1232	0.0000	0.1598	-0.0002	0.0000	0.0073
$jpmc_{12m}$	0.0572	0.7153	0.0000	0.1091	0.0000	0.0000	0.1183
$lloyds_{1m}$	0.9199	0.0001	0.0013	0.0038	0.0025	0.0000	0.0724
$lloyds_{3m}$	0.6662	0.1572	0.0000	0.1749	-0.0002	0.0000	0.0020
$lloyds_{12m}$	0.0581	0.7330	0.0000	0.1114	0.0000	0.0000	0.0975
$rabobank_{1m}$	0.9022	0.0006	0.0015	0.0120	0.0026	0.0000	0.0810
$rabobank_{3m}$	0.6442	0.1685	0.0000	0.1781	-0.0002	0.0000	0.0094
$rabobank_{12m}$	0.0740	0.6867	0.0000	0.1216	0.0000	0.0000	0.1177
$rboscotland_{1m}$	0.9102	0.0006	0.0012	0.0122	0.0023	0.0000	0.0735
$rboscotland_{3m}$	0.6388	0.1751	0.0000	0.1808	-0.0002	0.0000	0.0055
$rboscotland_{12m}$	0.0592	0.6820	0.0000	0.1083	0.0000	0.0000	0.1505
ubs_{1m}	0.9131	0.0004	0.0012	0.0108	0.0023	0.0000	0.0721
ubs_{3m}	0.6595	0.1621	0.0000	0.1767	-0.0002	0.0000	0.0019
ubs_{12m}	0.0617	0.7026	0.0000	0.1123	0.0000	0.0000	0.1234

Table 9: Proportion of Variance of Spreads Attributable to Each Component (GBP)							
	var(L)	var (C)	var(X)	cov(L,C)	cov(L,X)	cov(C,X)	var(e)
$barclays_{1m}$	0.9964	0.0000	0.0000	0.0000	0.0000	0.0000	0.0036
$barclays_{3m}$	0.5686	0.1710	0.0000	0.2161	0.0000	0.0000	0.0442
$barclays_{12m}$	0.1462	0.6117	0.0000	0.2071	0.0000	0.0000	0.0349
$citibank_{1m}$	0.9605	0.0019	0.0000	0.0292	0.0000	0.0000	0.0084
$citibank_{3m}$	0.5556	0.1660	0.0000	0.2105	0.0000	0.0000	0.0679
$citibank_{12m}$	0.2036	0.5581	0.0000	0.2337	0.0000	0.0000	0.0046
$deutschebank_{1m}$	0.9894	0.0000	0.0000	0.0006	0.0000	0.0000	0.0100
$deutschebank_{3m}$	0.5797	0.1621	0.0000	0.2124	0.0000	0.0000	0.0458
$deutschebank_{12m}$	0.3039	0.4289	0.0000	0.2503	0.0000	0.0000	0.0169
$jpmc_{1m}$	0.9899	0.0000	0.0000	0.0009	0.0000	0.0000	0.0092
$jpmc_{3m}$	0.6276	0.1232	0.0000	0.1928	0.0000	0.0000	0.0564
$jpmc_{12m}$	0.2736	0.4696	0.0000	0.2484	0.0000	0.0000	0.0084
$lloyds_{1m}$	0.9924	0.0001	0.0000	0.0064	0.0000	0.0000	0.0011
$lloyds_{3m}$	0.5633	0.1735	0.0000	0.2167	0.0000	0.0000	0.0464
$lloyds_{12m}$	0.2064	0.5553	0.0000	0.2346	0.0000	0.0000	0.0037
$rabobank_{1m}$	0.9661	0.0008	0.0000	0.0191	0.0000	0.0000	0.0140
$rabobank_{3m}$	0.5645	0.1652	0.0000	0.2117	0.0000	0.0000	0.0586
$rabobank_{12m}$	0.2704	0.4706	0.0000	0.2473	0.0000	0.0000	0.0117
$rboscotland_{1m}$	0.9746	0.0010	0.0000	0.0219	0.0000	0.0000	0.0024
$rboscotland_{3m}$	0.5044	0.2201	0.0000	0.2309	0.0000	0.0000	0.0446
$rboscotland_{12m}$	0.1706	0.5986	0.0000	0.2215	0.0000	0.0000	0.0093
ubs_{1m}	0.9749	0.0008	0.0000	0.0191	0.0000	0.0000	0.0052
ubs_{3m}	0.5332	0.1896	0.0000	0.2204	0.0000	0.0000	0.0568
ubs_{12m}	0.2207	0.5369	0.0000	0.2386	0.0000	0.0000	0.0037

Table 10: Proportion of Variance of Spreads Attributable to Each Component (EUR)							
	var(L)	var (C)	var(X)	cov(L,C)	cov(L,X)	cov(C,X)	var(e)
$barclays_{1m}$	0.9792	0.0000	0.0000	0.0000	0.0000	0.0000	0.0208
$barclays_{3m}$	0.4124	0.2921	0.0000	0.2244	0.0000	0.0000	0.0711
$barclays_{12m}$	0.0401	0.7761	0.0000	0.1137	0.0000	0.0000	0.0701
$citibank_{1m}$	0.9506	0.0033	0.0000	0.0362	0.0000	0.0000	0.0099
$citibank_{3m}$	0.4276	0.2956	0.0000	0.2299	0.0000	0.0000	0.0468
$citibank_{12m}$	0.0587	0.7392	0.0000	0.1346	0.0000	0.0000	0.0675
$deutschebank_{1m}$	0.9394	0.0000	0.0000	0.0008	0.0000	0.0000	0.0598
$deutschebank_{3m}$	0.3835	0.3139	0.0000	0.2243	0.0000	0.0000	0.0783
$deutschebank_{12m}$	0.1060	0.6813	0.0000	0.1737	0.0000	0.0000	0.0391
$jpmc_{1m}$	0.9963	0.0000	0.0000	0.0012	0.0000	0.0000	0.0025
$jpmc_{3m}$	0.4955	0.2289	0.0000	0.2177	0.0000	0.0000	0.0579
$jpmc_{12m}$	0.0945	0.6812	0.0000	0.1639	0.0000	0.0000	0.0604
$lloyds_{1m}$	0.9866	0.0002	0.0000	0.0081	0.0000	0.0000	0.0051
$lloyds_{3m}$	0.4056	0.3084	0.0000	0.2287	0.0000	0.0000	0.0573
$lloyds_{12m}$	0.0439	0.7628	0.0000	0.1180	0.0000	0.0000	0.0753
$rabobank_{1m}$	0.9554	0.0014	0.0000	0.0237	0.0000	0.0000	0.0194
$rabobank_{3m}$	0.3925	0.3066	0.0000	0.2243	0.0000	0.0000	0.0767
$rabobank_{12m}$	0.0895	0.6890	0.0000	0.1604	0.0000	0.0000	0.0611
$rboscotland_{1m}$	0.9639	0.0018	0.0000	0.0269	0.0000	0.0000	0.0074
$rboscotland_{3m}$	0.3519	0.3569	0.0000	0.2291	0.0000	0.0000	0.0620
$rboscotland_{12m}$	0.0340	0.7848	0.0000	0.1053	0.0000	0.0000	0.0758
ubs_{1m}	0.9394	0.0015	0.0000	0.0244	0.0000	0.0000	0.0346
ubs_{3m}	0.3877	0.3353	0.0000	0.2331	0.0000	0.0000	0.0438
ubs_{12m}	0.0628	0.7438	0.0000	0.1396	0.0000	0.0000	0.0538

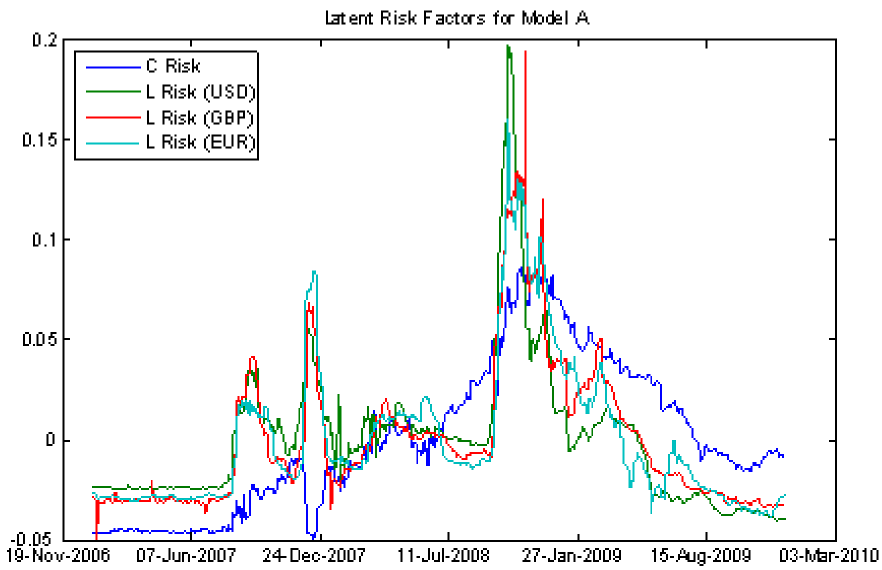

Latent Risk Factors for Model A
C Risk
L Risk (USD)
L Risk (GBP)
L Risk (EUR)
0.2
0.15
0.1
0.05
0
-0.05
19-Nov-2006
07-Jun-2007
24-Dec-2007
11-Jul-2008
27-Jan-2009
15-Aug-2009
03-Mar-2010

Figure 7

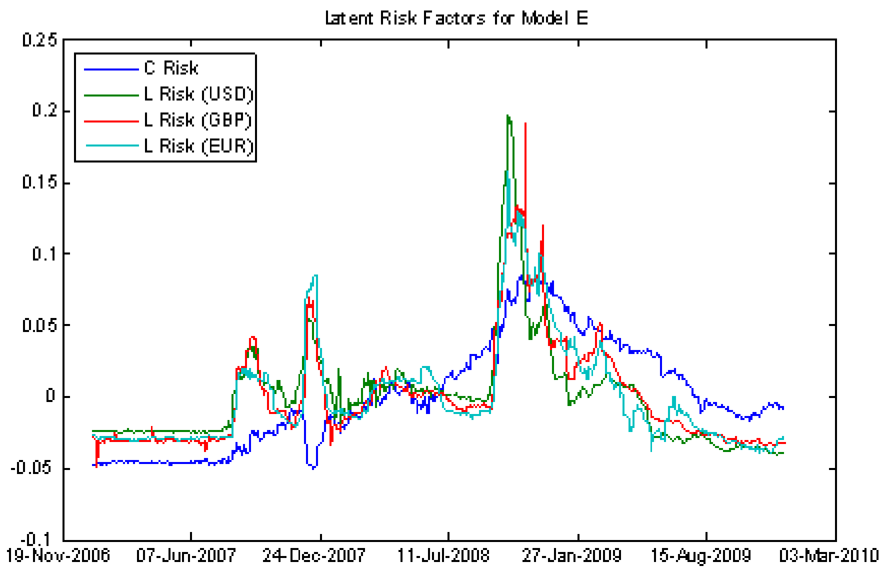

Latent Risk Factors for Model E
C Risk
L Risk (USD)
L Risk (GBP)
L Risk (EUR)
0.25
0.2
0.15
0.1
0.05
0
-0.05
-0.1
19-Nov-2006
07-Jun-2007
24-Dec-2007
11-Jul-2008
27-Jan-2009
15-Aug-2009
03-Mar-2010

Figure 8

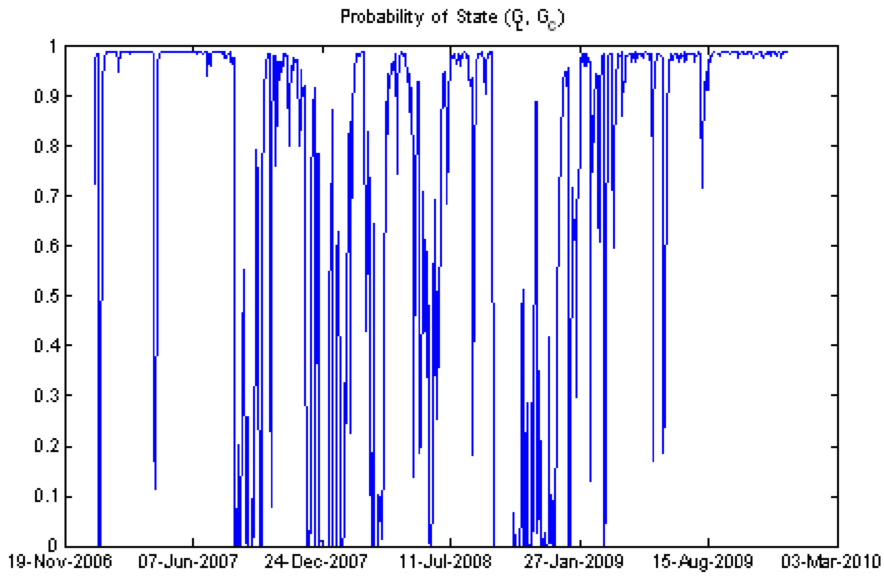

Probability of State (G_L, G_C)
19-Nov-2006
07-Jun-2007
24-Dec-2007
11-Jul-2008
27-Jan-2009
15-Aug-2009
03-Mar-2010

Figure 9

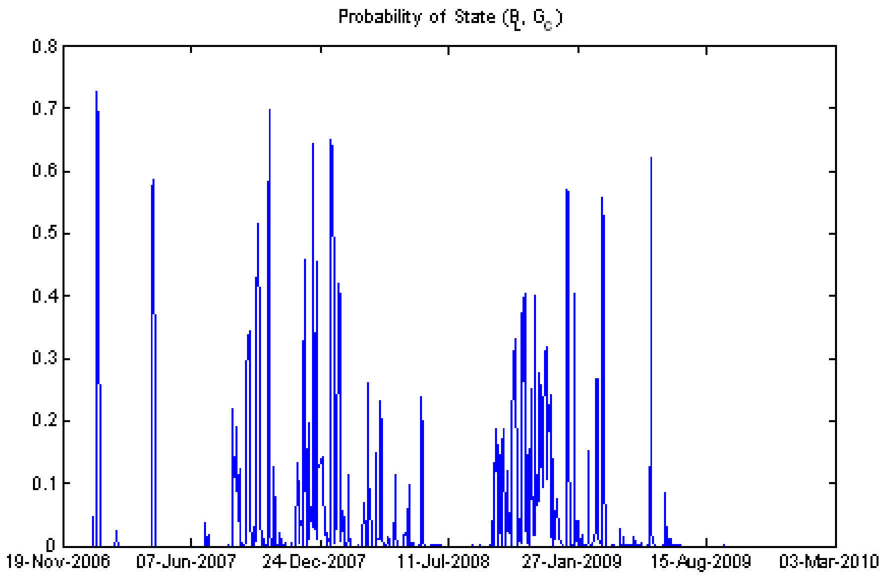

Probability of State (B_L, G_C)
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
19-Nov-2006
07-Jun-2007
24-Dec-2007
11-Jul-2008
27-Jan-2009
15-Aug-2009
03-Mar-2010

Figure 10

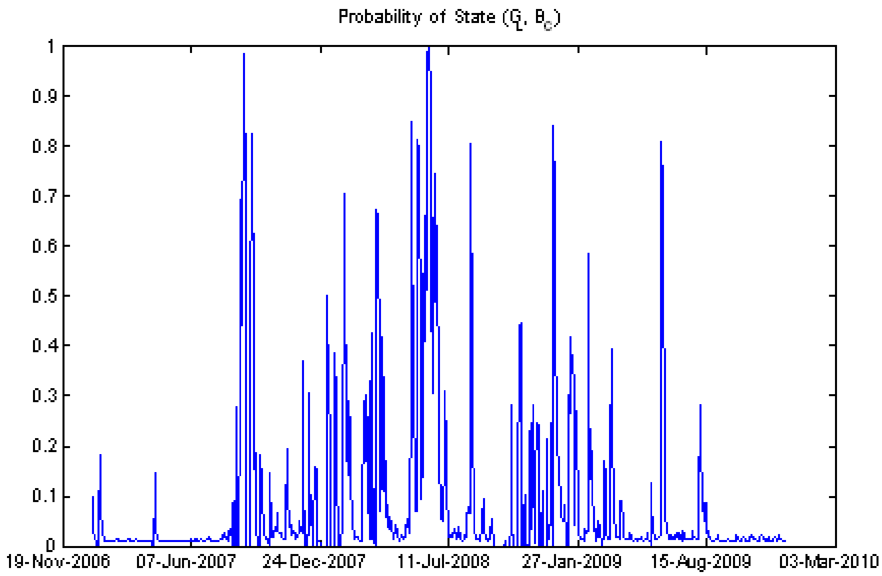

Probability of State (G_L, B_C)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
19-Nov-2006
07-Jun-2007
24-Dec-2007
11-Jul-2008
27-Jan-2009
15-Aug-2009
03-Mar-2010

Figure 11

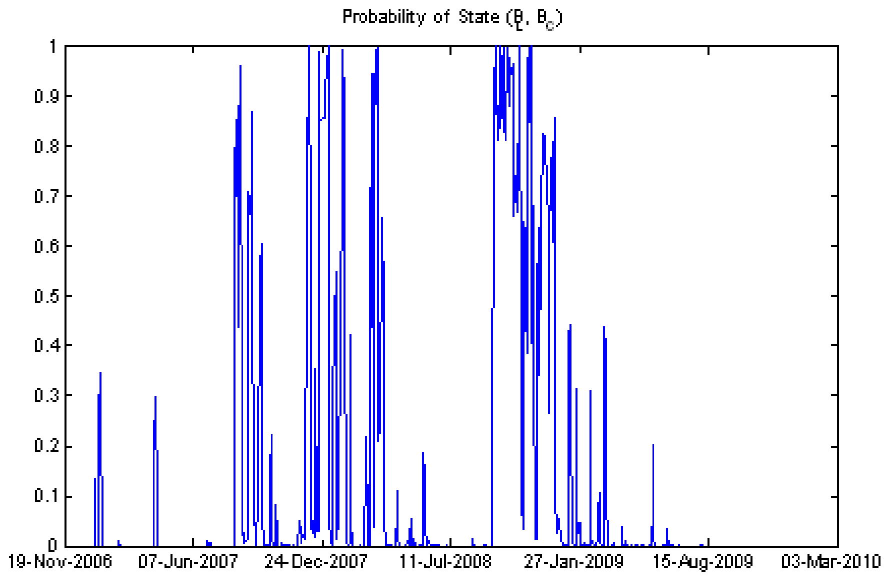


Figure 12

4 Empirical Results Involving Different Identification Assumptions

In this section, we present the empirical results where we restrict the factor loading for the term $i = 2$ to unity. Variance decomposition results for EUR show a pattern that differs from that of USD and GBP, which might be caused by the non-negligible correlation between L for EUR and C.

Table 11: Model Comparison

	BIC	AIC
Model A	-3.048	-4.146
Model B	-2.697	-3.770
Model C	-2.873	-3.946
Model D	-2.467	-3.515
Model E	-3.115	-4.137
Model F	-2.779	-3.795
Model G	-2.915	-3.931
Model H	-2.495	-3.505

Table 12: Posterior Mean of Transition Probabilities
(Posterior standard deviations in parentheses)

	(G_L, G_C)	(B_L, G_C)	(G_L, B_C)	(B_L, B_C)
(G_L, G_C)	0.948 (0.012)	0.257 (0.165)	0.225 (0.127)	0.086 (0.039)
(B_L, G_C)	0.010 (0.007)	0.273 (0.157)	0.059 (0.064)	0.028 (0.025)
(G_L, B_C)	0.015 (0.010)	0.157 (0.140)	0.283 (0.144)	0.094 (0.049)
(B_L, B_C)	0.027 (0.012)	0.312 (0.195)	0.432 (0.150)	0.791 (0.052)

Table 13: Proportion of Variance of Spreads Attributable to Each Component (USD)							
	var(L)	var (C)	var(X)	cov(L,C)	cov(L,X)	cov(C,X)	var(e)
$barclays_{1m}$	0.8649	0.1428	0.0000	-0.0449	0.0000	0.0000	0.0373
$barclays_{3m}$	0.6123	0.4063	0.0008	-0.0636	-0.0019	-0.0007	0.0470
$barclays_{12m}$	0.1026	0.9225	0.0000	-0.0393	0.0000	0.0000	0.0142
$btmufj_{1m}$	0.8287	0.2160	0.0000	-0.0540	0.0000	0.0000	0.0094
$btmufj_{3m}$	0.5612	0.4765	0.0009	-0.0660	-0.0020	-0.0008	0.0302
$btmufj_{12m}$	0.1157	0.9216	0.0000	-0.0417	0.0000	0.0000	0.0044
$citibank_{1m}$	0.8590	0.1899	0.0000	-0.0516	0.0000	0.0000	0.0028
$citibank_{3m}$	0.4396	0.0000	0.0011	0.0000	-0.0020	0.0000	0.5613
$citibank_{12m}$	0.1135	0.9235	0.0000	-0.0413	0.0000	0.0000	0.0043
$deutschebank_{1m}$	0.8673	0.1761	0.0000	-0.0499	0.0000	0.0000	0.0066
$deutschebank_{3m}$	0.5621	0.4564	0.0009	-0.0646	-0.0020	-0.0008	0.0482
$deutschebank_{12m}$	0.1462	0.8921	0.0000	-0.0461	0.0000	0.0000	0.0079
$hbos_{1m}$	0.8996	0.1120	0.0000	-0.0405	0.0000	0.0000	0.0289
$hbos_{3m}$	0.7227	0.2078	0.0007	-0.0494	-0.0020	-0.0005	0.1207
$hbos_{12m}$	0.4815	0.3007	0.0000	-0.0485	0.0000	0.0000	0.2663
$hsbc_{1m}$	0.8724	0.1748	0.0000	-0.0499	0.0000	0.0000	0.0027
$hsbc_{3m}$	0.5461	0.4757	0.0010	-0.0650	-0.0021	-0.0009	0.0452
$hsbc_{12m}$	0.1311	0.9090	0.0000	-0.0441	0.0000	0.0000	0.0040
$jpmc_{1m}$	0.8877	0.1540	0.0000	-0.0472	0.0000	0.0000	0.0056
$jpmc_{3m}$	0.5126	0.4980	0.0010	-0.0645	-0.0021	-0.0009	0.0558
$jpmc_{12m}$	0.0927	0.9356	0.0000	-0.0376	0.0000	0.0000	0.0094
$lloyds_{1m}$	0.8598	0.1902	0.0000	-0.0516	0.0000	0.0000	0.0016
$lloyds_{3m}$	0.5172	0.5038	0.0010	-0.0651	-0.0020	-0.0009	0.0460
$lloyds_{12m}$	0.1100	0.9256	0.0000	-0.0408	0.0000	0.0000	0.0051
$rabobank_{1m}$	0.8415	0.1997	0.0000	-0.0523	0.0000	0.0000	0.0111
$rabobank_{3m}$	0.4892	0.5206	0.0010	-0.0644	-0.0020	-0.0009	0.0565
$rabobank_{12m}$	0.1051	0.9238	0.0000	-0.0398	0.0000	0.0000	0.0109
$rboscotland_{1m}$	0.8413	0.1979	0.0000	-0.0521	0.0000	0.0000	0.0129
$rboscotland_{3m}$	0.5271	0.4993	0.0009	-0.0654	-0.0019	-0.0008	0.0410
$rboscotland_{12m}$	0.0880	0.9349	0.0000	-0.0366	0.0000	0.0000	0.0137
ubs_{1m}	0.8592	0.1911	0.0000	-0.0517	0.0000	0.0000	0.0014
ubs_{3m}	0.5241	0.5035	0.0009	-0.0656	-0.0020	-0.0008	0.0398
ubs_{12m}	0.0992	0.9304	0.0000	-0.0388	0.0000	0.0000	0.0091
$westlb_{1m}$	0.8273	0.2133	0.0000	-0.0536	0.0000	0.0000	0.0131
$westlb_{3m}$	0.5125	0.5246	0.0009	-0.0662	-0.0019	-0.0009	0.0310
$westlb_{12m}$	0.1058	0.9223	0.0000	-0.0399	0.0000	0.0000	0.0118

Table 14: Proportion of Variance of Spreads Attributable to Each Component (GBP)							
	var(L)	var (C)	var(X)	cov(L,C)	cov(L,X)	cov(C,X)	var(e)
$barclays_{1m}$	0.6467	0.3521	0.0000	-0.0024	0.0000	0.0000	0.0036
$barclays_{3m}$	0.3563	0.6093	0.0000	-0.0023	0.0000	0.0000	0.0367
$barclays_{12m}$	0.1239	0.8419	0.0000	-0.0016	0.0000	0.0000	0.0358
$btmufj_{1m}$	0.5813	0.4139	0.0000	-0.0024	0.0000	0.0000	0.0073
$btmufj_{3m}$	0.3382	0.6222	0.0000	-0.0023	0.0000	0.0000	0.0419
$btmufj_{12m}$	0.2363	0.7215	0.0000	-0.0021	0.0000	0.0000	0.0442
$citibank_{1m}$	0.6523	0.3411	0.0000	-0.0024	0.0000	0.0000	0.0090
$citibank_{3m}$	0.3353	0.0000	0.0000	0.0000	0.0000	0.0000	0.6647
$citibank_{12m}$	0.2295	0.7222	0.0000	-0.0020	0.0000	0.0000	0.0503
$deutschebank_{1m}$	0.7115	0.2830	0.0000	-0.0022	0.0000	0.0000	0.0077
$deutschebank_{3m}$	0.4049	0.5467	0.0000	-0.0023	0.0000	0.0000	0.0508
$deutschebank_{12m}$	0.2835	0.6578	0.0000	-0.0022	0.0000	0.0000	0.0609
$hbos_{1m}$	0.6838	0.1970	0.0000	-0.0018	0.0000	0.0000	0.1211
$hbos_{3m}$	0.5251	0.2344	0.0000	-0.0018	0.0000	0.0000	0.2422
$hbos_{12m}$	0.4683	0.2377	0.0000	-0.0017	0.0000	0.0000	0.2956
$hsbc_{1m}$	0.6205	0.3569	0.0000	-0.0024	0.0000	0.0000	0.0249
$hsbc_{3m}$	0.3494	0.5983	0.0000	-0.0023	0.0000	0.0000	0.0545
$hsbc_{12m}$	0.2348	0.7103	0.0000	-0.0020	0.0000	0.0000	0.0569
$jpmc_{1m}$	0.7423	0.2568	0.0000	-0.0022	0.0000	0.0000	0.0031
$jpmc_{3m}$	0.3885	0.5590	0.0000	-0.0023	0.0000	0.0000	0.0548
$jpmc_{12m}$	0.2803	0.6619	0.0000	-0.0021	0.0000	0.0000	0.0599
$lloyds_{1m}$	0.6755	0.3258	0.0000	-0.0023	0.0000	0.0000	0.0010
$lloyds_{3m}$	0.3529	0.6085	0.0000	-0.0023	0.0000	0.0000	0.0409
$lloyds_{12m}$	0.2328	0.7231	0.0000	-0.0020	0.0000	0.0000	0.0461
$rabobank_{1m}$	0.6685	0.3194	0.0000	-0.0023	0.0000	0.0000	0.0144
$rabobank_{3m}$	0.3734	0.5736	0.0000	-0.0023	0.0000	0.0000	0.0553
$rabobank_{12m}$	0.2675	0.6775	0.0000	-0.0021	0.0000	0.0000	0.0570
$rboscotland_{1m}$	0.6490	0.3507	0.0000	-0.0024	0.0000	0.0000	0.0027
$rboscotland_{3m}$	0.3411	0.6222	0.0000	-0.0023	0.0000	0.0000	0.0390
$rboscotland_{12m}$	0.1804	0.7846	0.0000	-0.0019	0.0000	0.0000	0.0369
ubs_{1m}	0.6455	0.3514	0.0000	-0.0024	0.0000	0.0000	0.0055
ubs_{3m}	0.3429	0.6103	0.0000	-0.0023	0.0000	0.0000	0.0491
ubs_{12m}	0.2311	0.7277	0.0000	-0.0020	0.0000	0.0000	0.0433
$westlb_{1m}$	0.6291	0.3694	0.0000	-0.0024	0.0000	0.0000	0.0039
$westlb_{3m}$	0.3393	0.6287	0.0000	-0.0023	0.0000	0.0000	0.0343
$westlb_{12m}$	0.2340	0.7215	0.0000	-0.0020	0.0000	0.0000	0.0466

Table 15: Proportion of Variance of Spreads Attributable to Each Component (EUR)							
	var(L)	var (C)	var(X)	cov(L,C)	cov(L,X)	cov(C,X)	var(e)
$barclays_{1m}$	0.6491	0.5159	0.0000	-0.2411	0.0000	0.0000	0.0760
$barclays_{3m}$	0.4585	0.7826	0.0000	-0.2496	0.0000	0.0000	0.0085
$barclays_{12m}$	0.2422	0.9011	0.0000	-0.1947	0.0000	0.0000	0.0515
$btmufj_{1m}$	0.5530	0.6240	0.0000	-0.2447	0.0000	0.0000	0.0678
$btmufj_{3m}$	0.4101	0.8287	0.0000	-0.2429	0.0000	0.0000	0.0041
$btmufj_{12m}$	0.2682	0.8998	0.0000	-0.2047	0.0000	0.0000	0.0367
$citibank_{1m}$	0.5867	0.5385	0.0000	-0.2341	0.0000	0.0000	0.1088
$citibank_{3m}$	0.1026	0.0000	0.0000	0.0000	0.0000	0.0000	0.8974
$citibank_{12m}$	0.2819	0.8877	0.0000	-0.2084	0.0000	0.0000	0.0389
$deutschebank_{1m}$	0.5419	0.5523	0.0000	-0.2278	0.0000	0.0000	0.1337
$deutschebank_{3m}$	0.3563	0.8570	0.0000	-0.2302	0.0000	0.0000	0.0170
$deutschebank_{12m}$	0.2400	0.9240	0.0000	-0.1962	0.0000	0.0000	0.0322
$hbos_{1m}$	0.7479	0.3678	0.0000	-0.2183	0.0000	0.0000	0.1026
$hbos_{3m}$	0.7527	0.3800	0.0000	-0.2225	0.0000	0.0000	0.0897
$hbos_{12m}$	0.6471	0.3828	0.0000	-0.2070	0.0000	0.0000	0.1771
$hsbc_{1m}$	0.5913	0.5363	0.0000	-0.2346	0.0000	0.0000	0.1070
$hsbc_{3m}$	0.4396	0.8014	0.0000	-0.2473	0.0000	0.0000	0.0063
$hsbc_{12m}$	0.2940	0.8817	0.0000	-0.2122	0.0000	0.0000	0.0364
$jpmc_{1m}$	0.6433	0.4592	0.0000	-0.2263	0.0000	0.0000	0.1237
$jpmc_{3m}$	0.4418	0.8012	0.0000	-0.2479	0.0000	0.0000	0.0049
$jpmc_{12m}$	0.2953	0.8774	0.0000	-0.2121	0.0000	0.0000	0.0393
$lloyds_{1m}$	0.6050	0.5360	0.0000	-0.2372	0.0000	0.0000	0.0962
$lloyds_{3m}$	0.4216	0.8181	0.0000	-0.2447	0.0000	0.0000	0.0050
$lloyds_{12m}$	0.2640	0.8976	0.0000	-0.2028	0.0000	0.0000	0.0413
$rabobank_{1m}$	0.5975	0.5292	0.0000	-0.2342	0.0000	0.0000	0.1074
$rabobank_{3m}$	0.4043	0.8192	0.0000	-0.2398	0.0000	0.0000	0.0163
$rabobank_{12m}$	0.2819	0.8855	0.0000	-0.2082	0.0000	0.0000	0.0407
$rboscotland_{1m}$	0.5819	0.5626	0.0000	-0.2383	0.0000	0.0000	0.0938
$rboscotland_{3m}$	0.4365	0.8029	0.0000	-0.2467	0.0000	0.0000	0.0072
$rboscotland_{12m}$	0.2298	0.9102	0.0000	-0.1906	0.0000	0.0000	0.0506
ubs_{1m}	0.5319	0.5929	0.0000	-0.2339	0.0000	0.0000	0.1091
ubs_{3m}	0.3893	0.8410	0.0000	-0.2384	0.0000	0.0000	0.0081
ubs_{12m}	0.2556	0.9024	0.0000	-0.2001	0.0000	0.0000	0.0421
$westlb_{1m}$	0.5440	0.5820	0.0000	-0.2343	0.0000	0.0000	0.1083
$westlb_{3m}$	0.3895	0.8430	0.0000	-0.2387	0.0000	0.0000	0.0063
$westlb_{12m}$	0.2550	0.9133	0.0000	-0.2010	0.0000	0.0000	0.0328

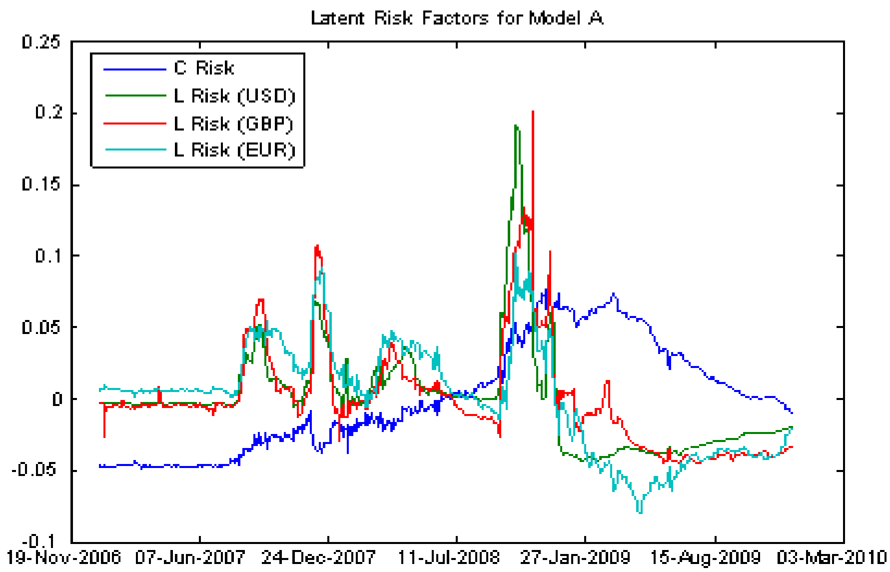

Latent Risk Factors for Model A
C Risk
L Risk (USD)
L Risk (GBP)
L Risk (EUR)
0.25
0.2
0.15
0.1
0.05
0
-0.05
-0.1
19-Nov-2006
07-Jun-2007
24-Dec-2007
11-Jul-2008
27-Jan-2009
15-Aug-2009
03-Mar-2010

Figure 13

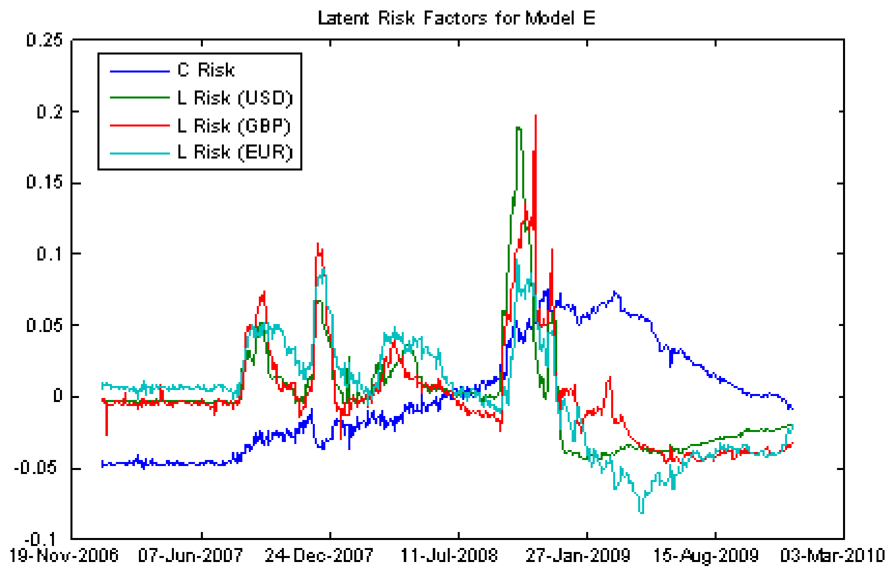
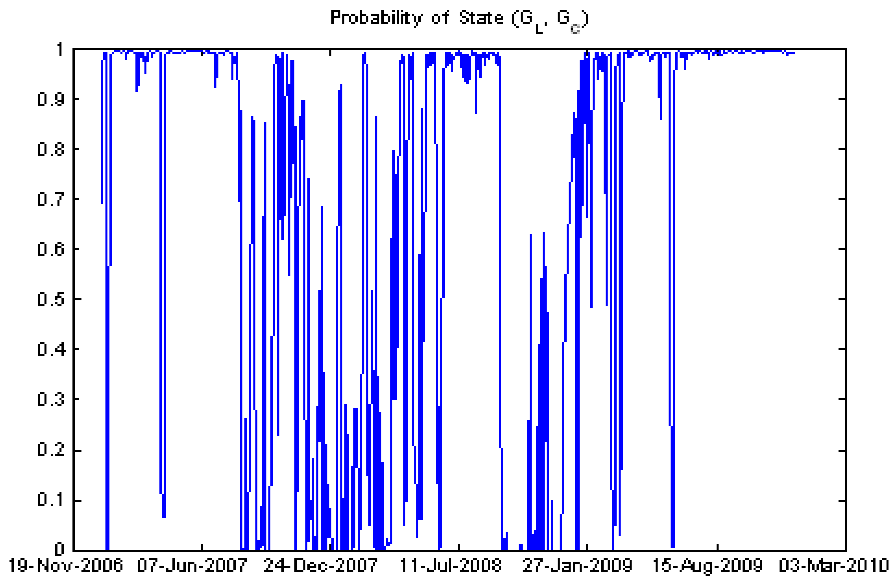

Latent Risk Factors for Model E
C Risk
L Risk (USD)
L Risk (GBP)
L Risk (EUR)
0.25
0.2
0.15
0.1
0.05
0
-0.05
-0.1
19-Nov-2006
07-Jun-2007
24-Dec-2007
11-Jul-2008
27-Jan-2009
15-Aug-2009
03-Mar-2010

Figure 14



Probability of State (G_L, G_C)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
19-Nov-2006
07-Jun-2007
24-Dec-2007
11-Jul-2008
27-Jan-2009
15-Aug-2009
03-Mar-2010

Figure 15

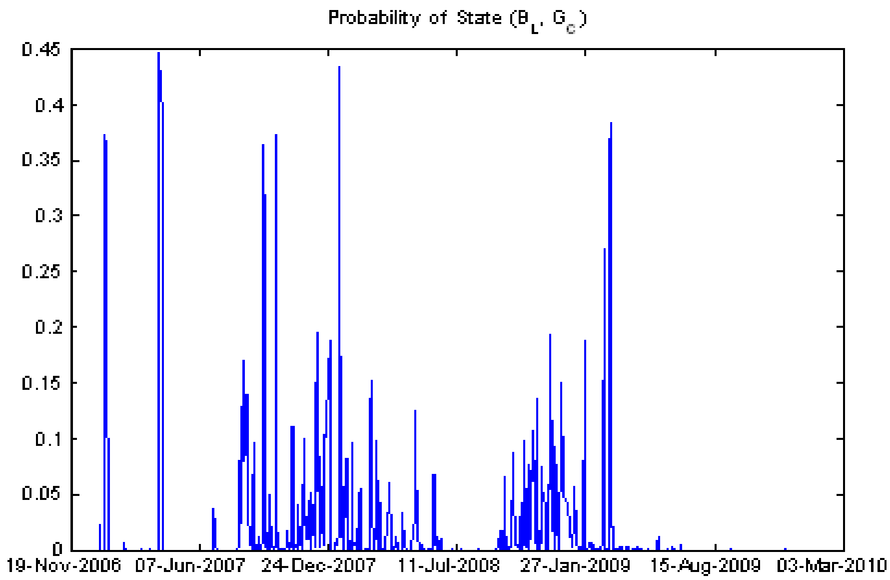

Probability of State (B_L, G_C)
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
19-Nov-2006
07-Jun-2007
24-Dec-2007
11-Jul-2008
27-Jan-2009
15-Aug-2009
03-Mar-2010

Figure 16

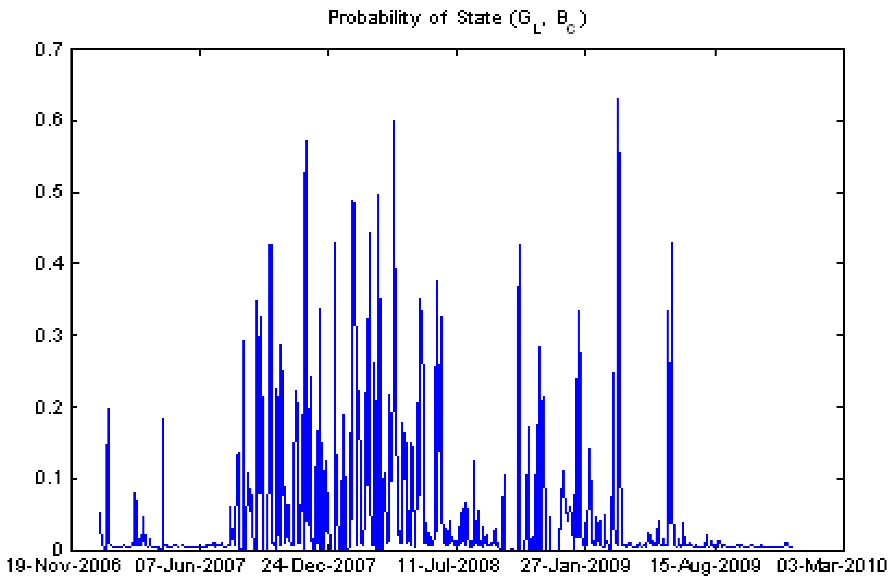

Probability of State (G_L, B_C)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
19-Nov-2006
07-Jun-2007
24-Dec-2007
11-Jul-2008
27-Jan-2009
15-Aug-2009
03-Mar-2010

Figure 17

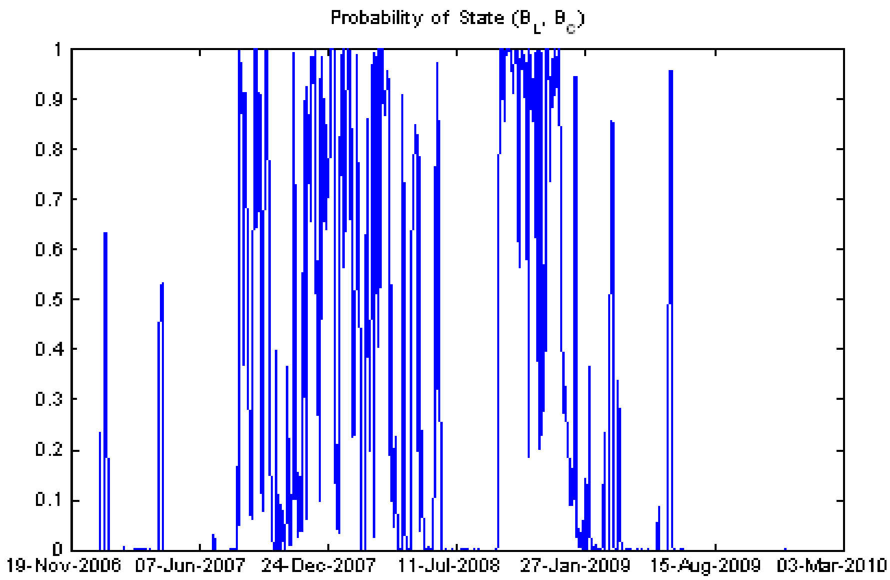


Figure 18

References

[1] Chib, S. (1996), Calculating Posterior Distributions and Modal Estimates in Markov Mixture Models, *Journal of Econometrics*, vol.75, p.79-97.

[2] Durbin, J. and S. J. Koopman (2001), T*ime Series Analysis by State Space Methods*, Oxford University Press, Oxford.

[3] Hamilton, J. D. (1989), *A new approach to the economic analysis of nonstationary time series and the business cycle*, Econometrica, vol.57, p.357-84.

[4] Kim, C-J and R. N. Nelson (1999), *State Space Models with Regime Switching*, MIT Press, Cambridge, MA.

[5] Koop, G. (2003), *Bayesian Econometrics*, Wiley, Chichester.